THE BRITISH SULPHUR CORPORATION LIMITED

Open File Report 88-6

A STUDY ON
POTASSIUM SULPHATE TECHNOLOGY
AND NORTH AMERICAN MARKETING

by

The British Sulphur Corporation Limited

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1988

A STUDY ON

POTASSIUM SULPHATE TECHNOLOGY

AND NORTH AMERICAN MARKETS

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EDITORIAL NOTE

Certain information obtained through Canadian Patents and Development Ltd. during the course of this study was on a process developed by Canada Centre for Mineral and Energy Technology (CANMET). Upon reviewing the consultant's conclusions on the CANMET process, CANMET advised that all reference to its process should be excluded. This has been done; hence, several pages in this report are blank and a number of paragraphs are missing.

Omission of the CANMET process does not change the conclusions drawn by the consultants.

This study was completed in June, 1985 but was not released because of secrecy agreements signed with companies who provided process data.

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EXECUTIVE SUMMARY

1. Ten potential processes for the production of potassium sulphate have been examined. These processes were: Mannheim Process; Chisso Process; Israel Chemicals Process; Pennzoil Process; Kali und Salz Process; The IMI (TAMI) Process; The PCS Glaserite Process; The Prodeco Process; The Atlantic Analytical (Pritchard Fraxon) Process.

2. Eight of these processes have been eliminated from further consideration related to a New Brunswick location with respect to non-availability of raw materials, unsuitability of the process and/or problems of utilization or disposal of by-products.

3. Two processes are recommended for further study: The IMI (TAMI) Process based on the utilization of gypsum as the sulphur source, and the Prodeco Process which suggests an elegant route to potassium sulphate without the problems of by-product hydrochloric acid sale or disposal.

4. Field work in the Eastern Provinces of Canada and the Eastern States of the United States suggest that there would be no problem in the disposal of the initial 30,000 tonnes of product from a development plant. The output from a 100,000 to 200,000 tonnes product commercial plant would require a proportion of the production to be designated for export. However, the advantages of a New Brunswick location related to the port of St. John, and the favourable freight components thereafter for ocean freight, would give a distinct advantage for New Brunswick production over any future production from a Saskatchewan location.

RECOMMENDATIONS

1. Discussions should take place with Israel Chemicals Ltd with respect to obtaining further information on the IMI ((TAMI) Institute for Research and Development Ltd) process using gypsum. Discussions should center on (i) the use of the process under licence (ii) a joint venture operations between Israel Chemicals (or one of its EEC subsidiaries such as Amfert or Guilini in West Germany) directed to the construction of a potassium sulphate plant in New Brunswick utilizing the high grade gypsum deposit at Hillsborough and/or (iii) additional development work as required to completely prove the process.

2. The necessary secrecy agreements to be exchanged with the patent owners of the Prodeco Process to allow a complete evaluation of the process and the claims thereof. In order to establish the operating capability and the reliability of this process (presently examined only in the laboratory) further laboratory investigation should be undertaken by an independent research laboratory to determine the operating parameters and to prove the process.

3. Additional field work should be carried out directed to the determination of offshore markets for potassium sulphate from a Saint John storage location, where the logistics of ocean freight, coupled with the low cost of domestic transporation from the new plant to the port of Saint John will show considerable net back advantages over product produced at the Potash Corporation of Saskatchewan's probable plant at Cory or Lanigan, Saskatchewan.

ADDENDUM

Recently Superphos have disclosed that they are considering production of potassium sulphate using a process with gypsum as the sulphur source. No details are presently available, but the Consultants consider that this process should be discussed and examined in conjunction with the Israel Chemicals Ltd process recommended, as both are based on gypsum technology.

METHODS OF MANUFACTURING POTASSIUM SULPHATE

BACKGROUND CHEMISTRY

CHARACTER OF SALTS

Ions and electrovalency

All the familiar potassium compounds of commerce, including potassium chloride, sulphate and nitrate, are typical members of a large group of chemical compounds known as **salts.** The essential character of salts is that in all condensed phases - solid, molten or in solution - they exist not in the form of neutral molecules but as electrically charged particles known as **ions.** Overall, however, they are electrically neutral because the total number of unit charges on the positive ions (or **cations**) balances the total number of negative charges on the negative ions (or **anions**).

The magnitude of the charge on an ion is always equivalent to a whole-number multiple of the charge on an electron, the basic unit of electrical charge, and the number of unit charges on an ion is referred to as its **valency.** Thus ions carrying only one charge are termed monovalent; those with two charges, divalent; those with three, trivalent, and so on.

The physical reasons why ions exist and why different ions carry different charges are complex and need not be considered here.

In many salts, including those of potassium, the cationic portion is derived from a metal, but there are also many non-metallic cations, the most familiar being the ammonium ion, NH_4^+. Non-metallic cations are usually molecular in character (i.e. made up of combinations of different elements), whereas metallic cations are simply positively charged atoms of the corresponding metallic element. Collectively, materials which form stable cations are known as **bases,** and the more readily a material forms a cation the more basic its character will be.

Conversely, most anions are derived from non-metals. They may be negatively charged atoms, as in the case of the sulphide ion, $S^=$, or halide ions such as chloride, Cl^-, fluoride, F^-, and so on; or they may be compound, as with sulphate, $SO_4^=$, and nitrate, NO_3^-. Occasionally, anions are derived from metals, almost always in combination with other elements - for example, aluminate, AlO_2^-, dichromate, $Cr_2O_7^=$. Collectively, materials which form stable anions are known as **acids,** and the more readily a material forms an anion the more acidic its character will be.

A **salt** is thus the product of the combination of a **base** and an **acid.** The most characteristic salts are those composed of ions from the most

strongly basic and the most strongly acidic substances, and the mineral acid salts of both potassium and sodium belong in this category.

Properties of salts

In the solid state salts are crystalline because the ions of salts arrange themselves in a characteristic regular spatial configuration known as a crystal lattice. Especially in the case of salts of strong acids and strong bases, the interionic forces which hold the ions in this structure are very strong, and much energy is needed to disrupt it. Such salts therefore tend to have very high melting points - sodium chloride (common salt), for example, melts at over 800°C.

Nevertheless, many salts will dissolve in water at ordinary temperatures, which entails disruption of the crystal lattice, and the reason this is possible is because water is what is known as a polar solvent. This means that, although it is not characteristically ionic, its molecules are electrically polarized. Thus there are strong attractions between the positive charge on a cation and the more negative end of a water molecule, as well as between the negative charge on an anion and the more positive end of the water molecule. Ions can thus become **solvated** - surrounded by water molecules - and when a salt is soluble it means that the energy gained from the formation of solvated ions exceeds the energy required to disperse the ions from their lattice structure. If the salt is insoluble, the solvation process is unable to provide enough energy to disrupt the crystal lattice. The higher the concentration of ions in solution, the more weakly each successive new ion will become solvated, and eventually the solvation energy exactly balances the energy needed to disperse further ions from the crystal, at which point the solution is saturated. But if additional energy is supplied (heat, for example), the equilibrium is disturbed in favour of solvation, which is why most salts tend to be more soluble in hot water than in cold.

There are relatively few polar solvents, and none of the commoner ones (liquid ammonia or methanol, for example) equals water in polarity. The majority of non-aqueous solvents are essentially non-polar, and in these solvation cannot occur, so salts - certainly those of strong acids and strong bases - are virtually insoluble in them.

An important property of salts, though not of immediate relevance to the present study, is their easy ability - in the molten state or in solution - to conduct an electric current. This conduction process is known as electrolysis because the salt is simultaneously decomposed. The positive ions are attracted to the negative electrode and the negative ions to the positive electrode, at which their respective charges are neutralized. This will result in the appearance of the material corresponding to the ion, unless this cannot exist in the environment in which it is generated, in which case it will react to produce different materials.

BASIS OF SALT CONVERSION PROCESSES

It is clear, then, that if dissimilar salts, or a salt and another highly ionized species such as an acid or a base, are dissolved in the same body of solvent, the resulting solution will contain ions derived from each. Assuming that the character of the individual ions themselves does not change, a reaction can only be said to have taken place if some of the ions associate in a such a way that a new substance physically separates out of the solution in some way. As long as everything remains in solution, the ions are just ions, and it is not strictly possible to identify any particular salt. Only when the conditions reach the point where a particular combination of ions can no longer remain in solution will there be any net chemical change in the system. This can result from the crystallization of a less soluble salt, which may comprise some or all of the ionic types present in the solution, or from the formation of a product which is volatile or is absorbed from the solution into another medium. Indeed, it may be possible to derive a variety of materials from the same mixed solution merely by altering the conditions. This is of fundamental importance in the design of any process for transforming one salt into another.

Available KCl-K_2SO_4 conversion process options

In the case of the potassium chloride/potassium sulphate conversion, the prerequisite is, obviously, a source of sulphate ions. Naturally, to be commercially attractive such a process must be devised to use a source of sulphate ions that is likely not only to be available to the prospective user but also to be available at reasonable cost. Obvious candidates are sulphuric acid - a very widely available industrial chemical - or common, low-value sulphate salts such as sodium and calcium sulphates.

If sulphuric acid is used, the chloride ions of the potassium chloride will combine with the hydrogen ions of the sulphuric acid to form hydrogen chloride, which, though dissociated into ions in aqueous solution, can also exist as neutral molecules in the form of a gas. It can therefore be removed by volatilization, and it can also be removed by contacting the aqueous reaction medium with a suitable water-immiscible, non-polar solvent, which abstracts the hydrogen chloride (as molecules), leaving the potassium and sulphate ions in the aqueous phase. The first option - volatilization - is the basis of furnace processes for converting potassium chloride to potassium sulphate. These include the long-established **Mannheim Kiln** process and a modern counterpart developed in Japan by **Chisso Corporation.** The alternative, solvent extraction principle has been used by **Israel Chemicals Ltd.**. A hybrid process, which uses volatilization as well as solvent extraction, has been proposed by **Pennzoil Co.**, but in that case, as will be explained, the solvent extraction is used to remove excess sulphuric acid rather than hydrogen chloride.

On account of certain economic and technical limitations of the furnace process, which are explained later, methods using sulphates rather than sulphuric acid have also been investigated. These are based on fractional crystallization and, for economic and logistical reasons, are generally designed to use a common, widely-available and low-priced sulphate. One sulphate which has been used - although, on first sight, it does not seem either common or especially low-priced - is magnesium sulphate. The reason is that it occurs in association with potassium chloride in some potash deposits, either combined with the potash as the mineral double salt kainite ($KCl.MgSO_4.3H_2O$) or alone, as the mineral kieserite ($MgSO_4.H_2O$), in adjacent seams which are exploited in the same mining operation. It therefore provides an on-the-spot source of sulphate which can be used for conversion of potassium chloride to potassium sulphate at the minehead. Another advantage of magnesium sulphate is that the conversion is quite simple and straightforward.

The magnesium sulphate route is exemplified by the process used by the West German potash producer, **Kali und Salz AG.**

Other processes, designed to work on calcium or sodium sulphates, are complicated by the fact that, in the presence of either sodium or calcium ions, potassium sulphate tends to crystallize as a double sulphate as soon as it is formed. The essence of the various processes using these two sources of sulphate, therefore, is either to inhibit the formation of the double salt to permit potassium sulphate to crystallize or to form and isolate the double salt and then decompose it to produce potassium sulphate. The chemistry of these processes will be explained in greater detail in individual accounts which follow.

An example of the former type is a second process under development by **Israel Chemicals Ltd,** in which the source of sulphate is calcium sulphate and the formation of the double salt is inhibited by addition of ammonia. In contrast, in the **PCS Glaserite** process, developed by Potash Corporation of Saskatchewan, the source of sulphate is sodium sulphate and the sodium-potassium double sulphate, glaserite, is deliberately allowed to form and is then separated and decomposed to yield potassium sulphate. Sodium sulphate is also the principal sulphate source in the **Prodeco** (USA) process, but here the double salt is not glaserite but syngenite, a calcium-potassium double salt. The calcium values are, however, retained in the processing circuit. Sulphuric acid is also used in this process, but it, too, is regenerated internally in the process.

These processes and their current commercial or development status are discussed individually in greater detail in the sections which follow.

Finally, a process based on ion exchange (**Pritchard-Fraxon**) has been proposed, but independent tests conducted for the Consultants have failed to verify its [illegible]erability. This process is described in an appendix to the main process appraisal.

PROCESSES USING SULPHURIC ACID AS PRIMARY SULPHATE SOURCE

FURNACE PROCESSES

THE MANNHEIM KILN PROCESS

The Mannheim Kiln process derives its name from a mechanical furnace developed at the end of the nineteenth century by Mannheim Verein, in Germany. Although there have been numerous modifications to the original design over the years, the furnaces in commercial operation today operate according to the same basic principles.

The Mannheim kiln can be used to produce either sodium or potassium sulphate. In the first case the raw material is sodium chloride (NaCl), in the second potassium chloride ("muriate of potash", KCl). In either case, the chloride is made to react with concentrated sulphuric acid, and gaseous hydrogen chloride is given off as a by-product of the reaction. Thus, operating companies which produce both sodium and potassium sulphate have the flexibility to increase the production of one product at the expense of the other if changing market conditions should justify it. The commercial operation of the process does, however, depend on the existence of a use or market for the by-product hydrogen chloride.

Outline description

The reaction in fact takes place in two discrete steps, in the first of which the bisulphate salt is formed and in the second the neutral sulphate:

$$MCl + H_2SO_4 \rightarrow MHSO_4 + HCl \quad (1)$$
$$MCl + MHSO_4 \rightarrow M_2SO_4 + HCl \quad (2)$$

Overall:

$$2MCl + H_2SO_4 \rightarrow M_2SO_4 + 2HCl \quad (3)$$

(M = Na or K)

Reaction 1 is exothermic and proceeds at relatively low temperatures, whereas reaction 2 is highly endothermic and requires temperatures in the order of 600-700°C to reach completion. Figure 1 shows the temperature dependence of the overall reaction.

Figure 2 shows the basic design of the sulphate furnace and Fig. 3 is a typical process flow diagram of a Mannheim Kiln process installation.

Potassium chloride (60% K_2O), ground to 100% <2mm and 90% <1mm, and 98% sulphuric acid are fed into the furnace near the centre of the enclosed circular saucer-shaped hearth. The mixture is continuously agitated and moved towards the periphery of the hearth by means of rotating rabble arms. The rotor commonly comprises four arms of equal length and is attached to a shaft running through the base of the hearth. This is driven electrically at 1-2 r/min. The maximum satisfactory length of the cast iron rabble arms is usually a little over 2m; above this limit the danger of failure in service is unacceptably high. This places a limit of 5-6m on the diameter of the furnace hearth, corresponding to a maximum daily output per furnace of about 25 tonnes of sodium sulphate or 27 tonnes of potassium sulphate.

The required heat is provided by passing hot combustion gases, produced by burning a fuel, over and round the hearth. A refractory-insulated muffle covering the hearth serves to moderate and distribute the heat and also segregates the process off-gas from the combustion gases. Usually some simple form of heat recovery system, such as a countercurrent heat exchanger preheating the combustion air, is employed to recover heat from the combustion gas. Fuel oil is currently the most common source of fuel used; ideally it is preheated to 85-100°C using low-pressure steam. The temperature in the furnace above the muffle can be as high as 1,600°C, but generally it is limited to 1,000°-1,400°C by recycling part of the combustion gas stream as a diluent. The combustion gas is discharged through a chimney after heat recovery.

Solid potassium sulphate is removed from the furnace at a temperature of approximately 400°C and is cooled to between 100°C and 150°C, usually indirectly with water. The product contains 50-52% K_2O, around 3-3.5% Cl^-, 3-4% of free H_2SO_4 and 0.1-0.3% moisture. It usually requires no further treatment, but in some cases calcium carbonate may be added to reduce the free sulphuric acid content down to 1.5%. After milling and classification, if necessary, it can be handled and stored equally well in bulk or in bags.

The hot off-gas produced in the furnace, which consists primarily of hydrogen chloride but also contains a minor proportion of sulphuric acid vapour and mist and any moisture that was present in the starting materials, is cooled in a water-cooled heat exchanger and then passed through a mist eliminator. The moderately concentrated hydrochloric acid condensate contains effectively all of the sulphuric acid vaporized in the furnace. The hydrogen chloride gas is then passed through an absorption tower to produce commercial-grade hydrochloric acid, with a concentration of 30-33 wt-% (19-20° Bé). Finally, the gas is passed through a two-stage scrubber/contact cooler before being discharged to the atmosphere.

Consumptions and product quality

The figures given here refer to the process depicted in Fig. 3.

Raw materials and utility consumptions (per tonne K_2SO_4 product)

Sulphuric acid (as 100% H_2SO_4)	587 kg
Potassium chloride (60% K_2O)	850 kg
Fuel oil	110kg
Electric power	30 kWh
Process water	$2m^3$

Hydrochloric acid product quality

HCl content	29-30%
Apparent density	1.15 g/ml
H_2SO_4	0.4%
Iron	0.005%
Cl_2	trace
Water	70-71%

Potassium sulphate product quality

K_2O	50%
Chloride	3%
H_2SO_4	4%
Humidity	0.2%

Potassium chloride raw material specification

To achieve the product qualities specified above, the potassium chloride used in the process should conform with the following requirements:

K_2O	60%
Moisture	not more than 0.3%
Iron	not more than 15 ppm
Particle size:	
<2mm	100%
<1mm	90%
Free of anticaking agents	

There are variations in the utilities consumption between the Mannheim process schemes of different designers. Another contractor, for example, specifies a lower fuel oil consumption (78-88 kg/tonne) but a higher electricity consumption (65 kWh/tonne) for its process.

Commercial considerations

An obvious requirement for any producer of potassium sulphate using potassium chloride as feedstock is that the difference between the market price of the product and that of potassium chloride will be sufficiently in excess of the cost of conversion to provide an adequate return on the necessary investment. Obviously, existing producers who have partially or totally written off the cost of plant will have lower capital-related costs than a new producer. Furthermore, manufacturers of material produced directly from brines and sulphate-bearing potash ores may often have a cost advantage over the full cost of manufacturing potassium sulphate from potassium chloride in a new facility. The economics of potassium sulphate production are considered in detail in a later section.

The minimum economic size of plant will probably have four furnaces, each capable of producing approximately 25 t/d of potassium sulphate. Allowing for maintenance down-time, the annual production potential of such a plant will be approximately 30,000 tonnes.

Probably the most important consideration facing a new producer is the market for and value of hydrochloric acid by-product. Hydrochloric acid is by-produced at a rate of approximately 1.05 tonnes per tonne of potassium sulphate. It can only be stored in specially designed tanks and cannot be discarded as waste because of the danger to the environment. The prospective Mannheim process operator therefore has to be assured of a constant outlet for this by-product if he is to avoid interrupting production. This and the fact that hydrochloric acid is hazardous to transport have led most operators hitherto to elect to consume the by-product hydrochloric acid on site in a downstream operation. Most existing producers also have the capability for producing the required sulphuric acid themselves, although there is no particular technical reason for doing so, beyond the consideration of security of supply.

Whether to produce sulphuric acid on site and use the hydrochloric acid in a captive process is obviously a decision that must be taken in the light of market conditions. The best safeguard for the operator is to build into the operation a reasonable degree of flexibility such that, for example, sulphuric acid can be produced on site or purchased as the market dictates, or hydrochloric acid can be consumed in the production of more than one down-stream product and also sold on the spot market, whichever proves most advantageous to the producer. The following sketches illustrate how two existing Mannheim process operations are set up.

EMC-Belgium

This company manufactures over 60% of the total world Mannheim-process production of potassium sulphate in its subsidiaries Tessenderlo Chemie and Limburg Chemie. The group's plants at Tessenderlo, Vilvoorde and Ham have a combined capacity of 1 million t/a of potassium sulphate and sodium sulphate. The sulphuric acid requirements are satisfied partly by on-site production and partly by purchase from nearby smelter operations on long-term contracts. The sulphuric acid production facilities include a 100,000-t/a sulphur-burning plant at Tessenderlo, a 107,000-t/a sulphur-burning plant at Vilvoorde (in two streams), and a 254,000-t/a pyrites-roasting plant at Ham (in three streams).

Hydrochloric acid is consumed by the group in the production of a total of 400,000 t/a of dicalcium phosphate (DCP) from phosphate rock for use in animal feed preparations at Tessenderlo and Ham. Large quantities of hydrochloric acid are also consumed at Tessenderlo in a 450,000-t/a vinyl chloride momomer (VCM) plant. Smaller quantities of hydrochloric acid are consumed at Vilvoorde in the production of DCP and gelatine from animal bones. The remaining hydrochloric acid produced is sold on the local spot market.

ERT, Spain

ERT is the second largest Mannheim-process producer of potassium sulphate, accounting for about 13% of world production by this route. In contrast to EMC, it has only one source of sulphuric acid and one outlet for its by-product hydrochloric acid. The 130,000-t/a potassium sulphate plant at Cartagena is supplied with sulphuric acid from a 650-t/d pyrites-based plant on the same site. Also on site, hydrochloric acid is consumed in a 270-t/d plant producing feed-grade DCP. In this instance, instead of having surplus hydrochloric acid for other uses, it is necessary to bring in supplementary acid from another source within the group.

Although, at first sight, the conversion of potassium chloride to potassium sulphate may appear economically attractive because of the large differential in price (currently greater than 100%), the complexity of the infrastructure necessary to ensure supplies of raw materials and outlets for the by-product greatly increase the capital investment and the risk involved. To be seriously considered for any project it is likely that much, if not all, of this infrastructure would have to exist already.

Fig. 1: Temperature Dependence of the Reaction:
$2KCl + H_2SO_4 \rightarrow K_2SO_4 + 2HCl$

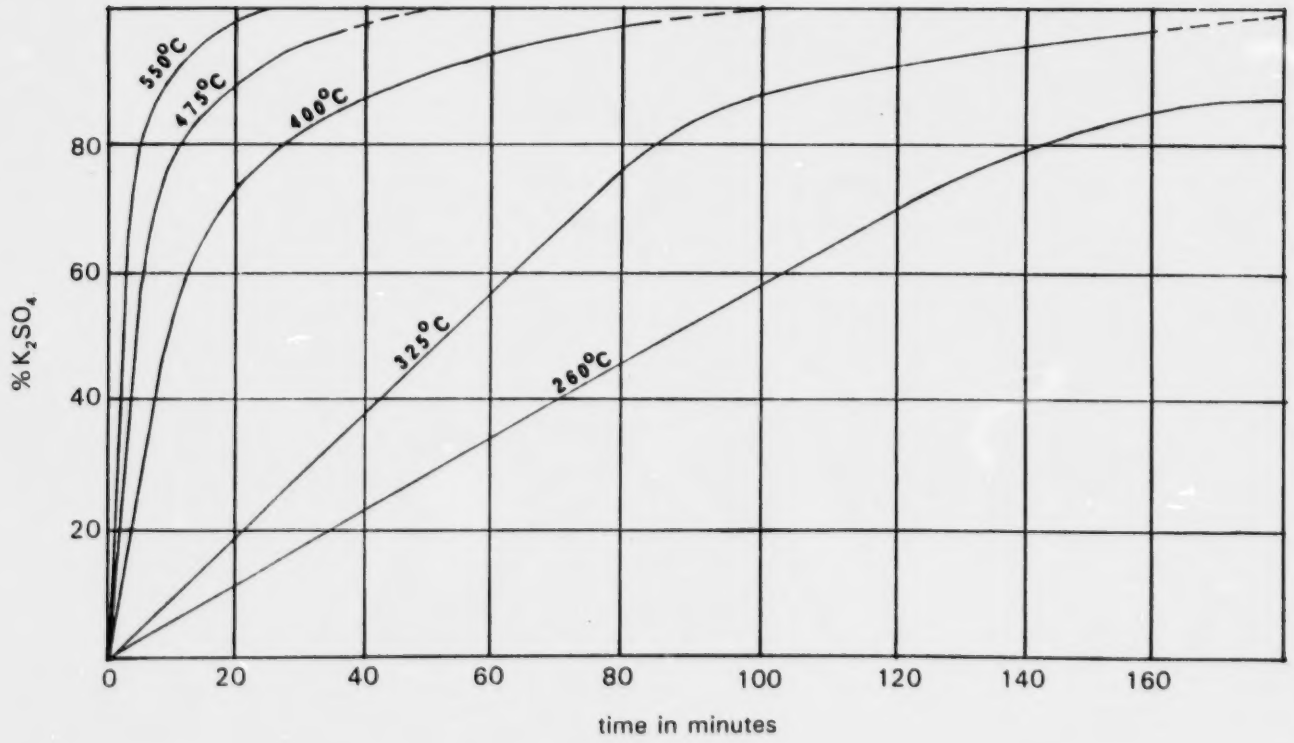


Fig. 2: Schematic Diagram of the Mannheim Furnace

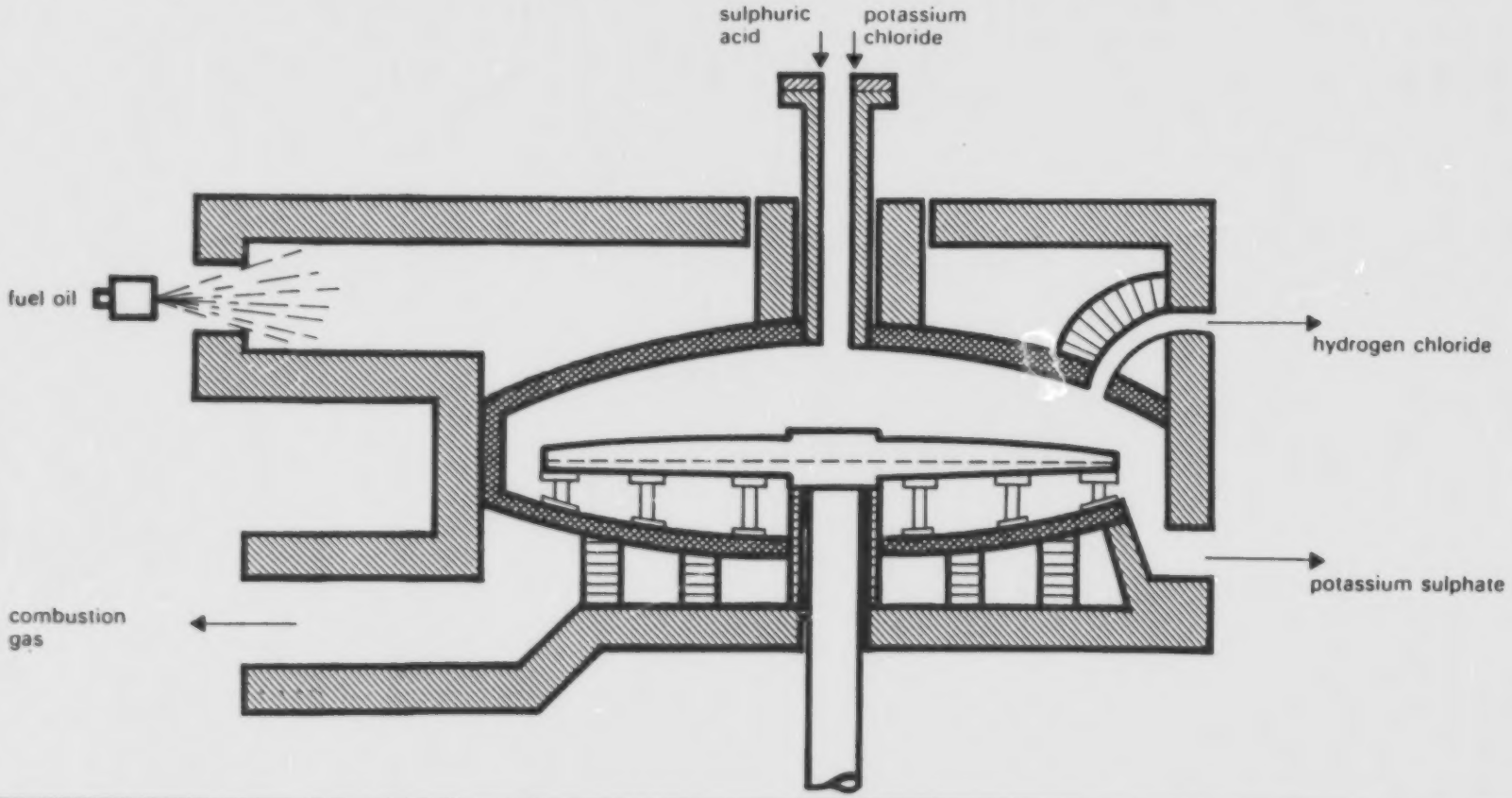
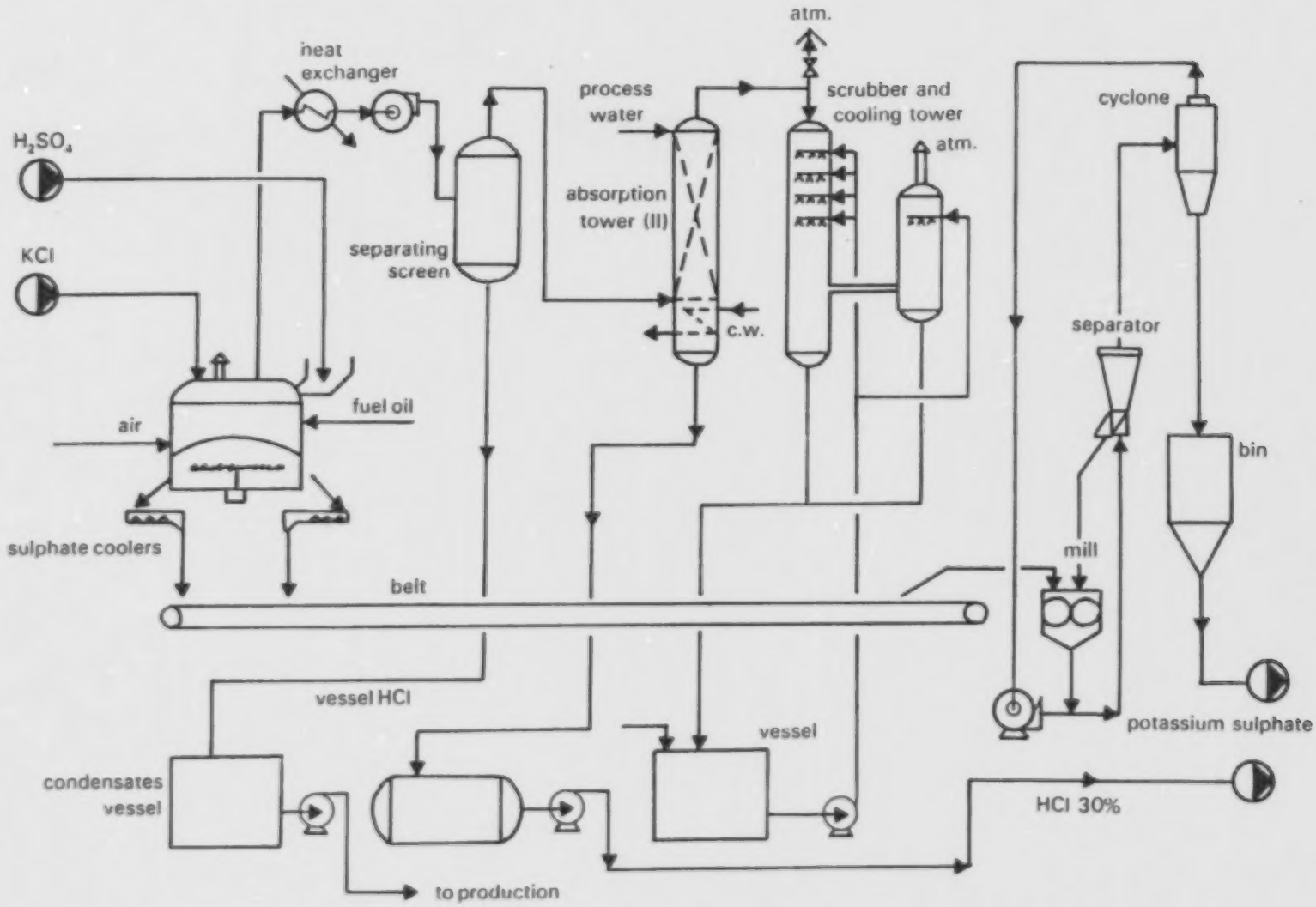


Fig. 3: Flow Diagram of a Typical Mannheim Kiln Potassium Sulphate Process



THE CHISSO PROCESS

Also a furnace process, the Chisso potassium sulphate process was originally introduced about 30 years ago and has been further developed and improved in the intervening years. Chisso is currently producing 40,000 t/a of potassium sulphate at its Minamata factory by this process, and it is also in use at two other plants in Japan, the newer of which - a 10,000-t/a unit at the Onahama works of Nippon Kasei Chemical Co. - went into operation in 1981. The process has also been used in two plants, of 20,000 t/a apiece, constructed very recently in the Republic of Korea.

Differences from the Mannheim Kiln

There are two significant differences between the Chisso process and the Mannheim Kiln process.

As mentioned in the account of the Mannheim Kiln, the decomposition of potassium chloride by sulphuric acid takes place in two stages, the first of which will, in fact, take place at room temperature. In the Mannheim Kiln, the potassium chloride and the sulphuric acid are introduced directly into the furnace and both stages of the reaction take place there. In the Chisso process, the potassium chloride and sulphuric acid are introduced first into a preliminary reactor, in which part of the potassium chloride is converted to potassium bisulphate (potassium hydrogen sulphate) at room temperature. The mixture of potassium bisulphate and potassium chloride is then introduced into the furnace, where they react together to produce potassium sulphate. Because a considerable proportion of the hydrogen chloride is evolved at low temperature from the preliminary reactor, less heat is lost in the off-gas from the furnace, and as a result the fuel consumption of the furnace is about 15% lower than in the Mannheim Kiln.

The other difference is in the design of the furnace itself. The Chisso furnace is smaller overall. And, in contrast to the dome muffle of the Mannheim Kiln and its cumbersome rabble arms rotating about a vertical axis, the Chisso furnace has an arch-type muffle which is claimed to be both cheaper and more durable, while the contents of the hearth are agitated by twin rotors on a horizontal shaft. These are of a considerably smaller diameter than the Mannheim rabble arm rotor and, again, are stated to be cheaper and less susceptible to wear and failure in service. For a furnace of a given capacity, Chisso claims an investment cost only half that of a Mannheim furnace, over twice the life and, consequently, lower maintenance costs.

Outline description

A flow diagram of the Chisso process is given in Fig. 4.

Potassium chloride is transported from the warehouse to the feed preparation section, where it is finely pulverized to more than 97% minus 32 mesh (Tyler) and dried by hot combustion gas from the furnaces to a moisture content of less than 0.5 wt-%. It then enters the preliminary reactors, where it is mixed with sulphuric acid; the $KCl:H_2SO_4$ mole ratio is strictly controlled. Reaction 1 takes place at ambient temperature and hydrogen chloride gas evolves.

$$KCl + H_2SO_4 \rightarrow KHSO_4 + HCl \qquad (1)$$

The hydrogen chloride is conducted to the absorption section.

The mixture of $KHSO_4$ and KCl resulting from the reaction in the preliminary reactors is passed to the furnaces, where reaction 2 proceeds at a strictly controlled high temperature.

$$KCl + KHSO_4 \rightarrow K_2SO_4 + HCl \qquad (2)$$

Crude potassium sulphate produced in the reactor furnaces is conveyed to the finishing section. Here it is first crushed and screened to a fine powder and then fed into a mixer, where it is treated with slaked lime to neutralize residual sulphuric acid.

Finally, the neutralized potassium sulphate is dried with hot gas in a dryer and sent to the warehouse. For applications such as bulk blending of fertilizers, the product is transformed into hardened flakes by compaction.

Hydrogen chloride gas evolved in the reactors is scrubbed with sulphuric acid to remove impurities and any sulphuric acid that may have been vaporized in the furnaces. The concentration in the scrubbing circuit is maintained at 75% by withdrawing a bleed stream and replacing it with concentrated acid. This partially diluted sulphuric acid is an unavoidable by-product of the process. The scrubbed furnace off-gas is then combined with the hydrogen chloride evolved in the prereactors and treated to remove the small amount of impurities by a Chisso proprietary purification process. It is then absorbed in water to produce high-concentration hydrochloric acid, which meets the food grade specification for the Japanese market.

Consumptions and material specifications

Materials consumption (per tonne K_2SO_4)

Potassium chloride	865 kg
Sulphuric acid (as 100% H_2SO_4)	665 kg
Slaked lime powder	25 kg
Alkali:	
Ammonia or	15 kg
Caustic soda	40 kg

Utilities consumption (per tonne K_2SO_4)

Cooling water (max. 25°C)	100 m^3
Process water	1.0 m^3
Steam (7 kg/cm^2 sat.)	20 kg
Electric power	120 kWh
Fuel oil (Bunker C)	50-70 litres

By-product credits (per tonne K_2SO_4)

35 wt-% hydrochloric acid (as 100% HCl)	370 kg
75+% sulphuric acid (as 100% H_2SO_4)	110 kg

Product quality

Potassium sulphate

K_2O	min. 50 wt-%
Cl^-	less than 3.0 wt-%
Free H_2SO_4	less than 0.2 wt-%

Hydrochloric acid

HCl	min. 35 wt-%
$SO_4^=$	less than 0.02%

Dilute sulphuric acid

H_2SO_4	min. 75 wt-%

Raw material quality

Potassium chloride

K_2O	min. 61.0 wt-%
Cl^-	min. 47.0 wt-%
Arsenic (as As_2O_3)	less than 0.1 ppm
Heavy metals (as Pb)	less than 3 ppm

Sulphuric acid

H_2SO_4	min. 98 wt-%
Arsenic (as As_2O_3)	less than 1.5 ppm
Heavy metals (as Pb)	less than 3 ppm

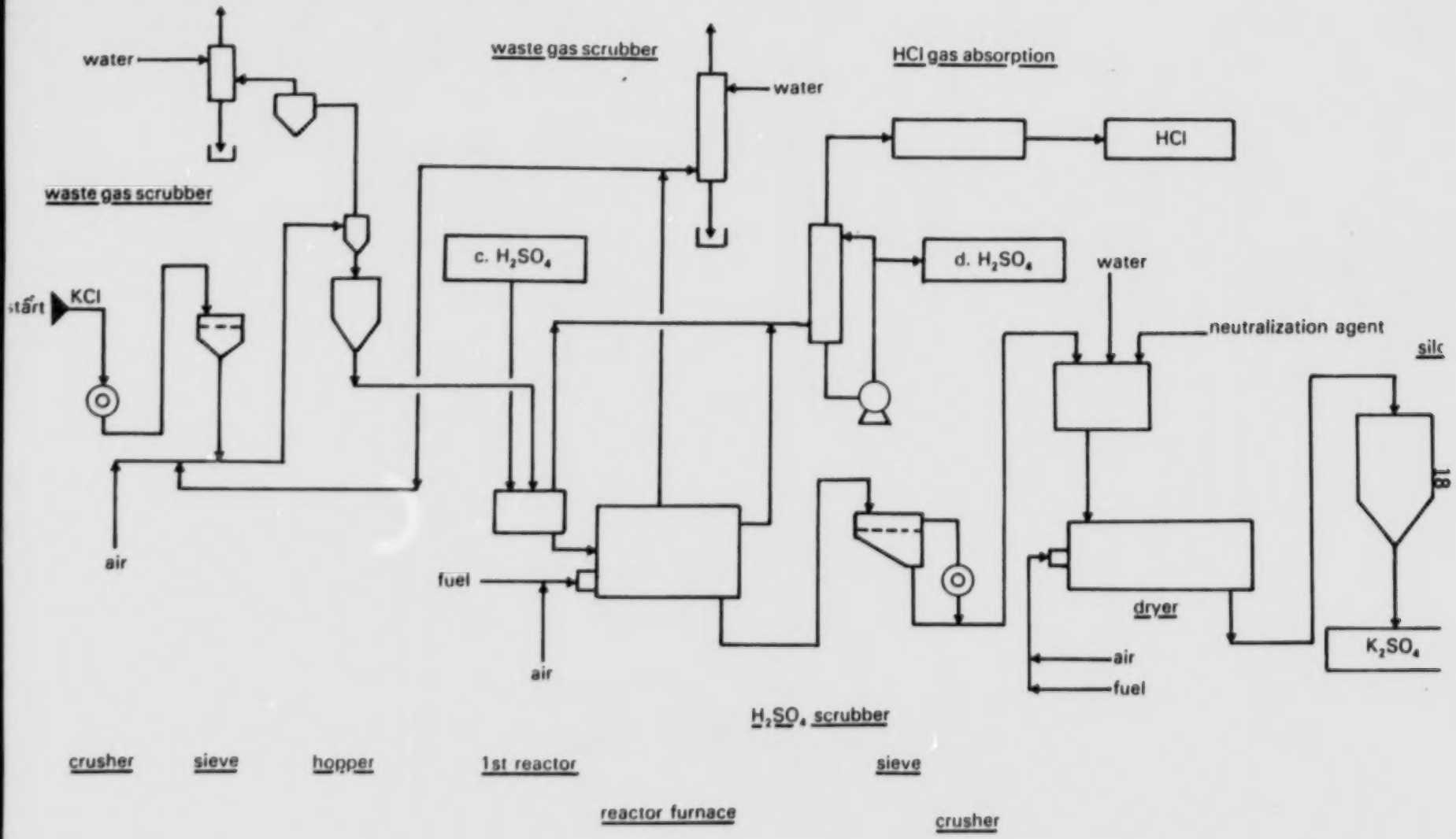
Slaked lime (for neutralization)

$Ca(OH)_2$	min. 90 wt-%

Alkali (for HCl purification)

Aqueous ammonia (as NH_3)	10 wt-%
- or -	
Caustic soda (as NaOH)	40 wt-%

Fig. 4: Flow Diagram of the Chisso Potassium Sulphate Process



SOLVENT EXTRACTION PROCESSES

THE ISRAEL CHEMICALS PROCESS

Process principle

It is clear from the description of the Chisso process that the first stage of the reaction of sulphuric acid with potassium chloride proceeds easily at normal temperatures. The result is a mixture of potassium bisulphate and potassium chloride, and to obtain potassium sulphate it is necessary to provide conditions under which further hydrogen chloride will be removed from the reaction zone. Both the processes considered so far have used strong heat to displace the hydrogen chloride as vapour and thus to make the second stage of the reaction proceed. As we have seen, this not only involves a considerable expenditure on fuel but also necessitates providing a furnace made of materials that can withstand the extremely corrosive nature of the process medium at the temperatures required, as well as some fairly sophisticated equipment to clean the hydrogen chloride gas and absorb it in water.

The Israel Chemicals process adopts a different technique to remove hydrogen chloride from the locus of reaction, which works under much less demanding conditions. It is based on solvent extraction, using an alcohol which is substantially immiscible with aqueous solutions, to remove the by-product HCl from the reaction mixture. A pilot plant is currently being built and, subject to favourable results being obtained, a 150,000-t/a commercial plant may be in operation by 1987.

Solvent extraction is a branch of technology in which Israel Chemicals has acquired considerable experience. In potash processing, it is in commercial use in a 220,000-t/a plant at its Haifa Chemicals subsidiary for producing potassium nitrate by the reaction of potassium chloride with nitric acid. The by-product hydrochloric acid is extracted into a mixture of pentanol isomers and the potassium nitrate crystallizes and can be filtered off from the brine, which is recycled. To promote crystallization of the potassium nitrate it is necessary to keep the reaction mixture at a temperature of $5^{o}C$. The hydrogen chloride is recovered from the solvent phase as 20% aqueous hydrochloric acid by water washing. This, in turn, is used for acidulating phosphate rock, technical-grade phosphoric acid being recovered from the resulting mixed solution by, once again, solvent extraction. But because an excess of nitric acid has to be used in the first stage of the process, a substantial amount of free nitric acid is present in the solvent extract, so additional solvent treatment stages have to be provided to recover it and prevent it from leaving the process in the by-product hydrochloric acid.

The potassium sulphate process is analogous to the potassium nitrate process; the driving force is, once again, provided by the extraction of

HCl into an organic phase and the solid product precipitates during the solvent extraction. In this case, however, the process operates satisfactorily at ambient temperature and, because sulphuric acid is substantially less soluble in the pentanol solvent than hydrogen chloride, it is unnecessary to include a separate solvent treatment to recover it.

The system K_2O-H_2SO_4-H_2O differs from the system K_2O-HNO_3-H_2O in that a series of salts of decreasing acidity exists, from $KHSO_4.nH_2SO_4$ to K_2SO_4. In the early stages of development, the conversion was conducted in three separate stages to exploit this peculiarity (Fig. 5). In the first, the conditions of acidity were chosen so that potassium bisulphate, $KHSO_4$, would crystallize. The solid was separated and passed to the next stage, in which the conditions were chosen so that a double salt of potassium bisulphate and potassium sulphate, $KHSO_4.K_2SO_4$, would crystallize:

$$2KHSO_4 + 2KCl \longrightarrow KHSO_4.K_2SO_4 + 2HCl \qquad (4)$$

This, in turn, was separated and passed to the third stage, in which K_2SO_4 was formed. The brine in each stage was recycled. The solvent flowed successively through the three stages in countercurrent.

In this way the concentration of the by-product hydrochloric acid was maximized (to about 12%) and the quantity of solvent in circulation could be kept to a minimum. However, the acid produced in this system contained about 2.5% H_2SO_4, and the need for three reactors and three sets of solids separation equipment was obviously a disadvantage from the point of view of capital cost.

Outline description of present process

The process arrangement appears now to have been simplified (Fig. 6) to use a single reactor to produce K_2SO_4 directly. The hydrochloric acid by-product is slightly less concentrated (10%) but contains only 1% H_2SO_4. Solid potassium chloride and suitably diluted sulphuric acid are fed to a reaction vessel and contacted in countercurrent with recycled lean pentanol solvent. Hydrogen chloride is extracted into the organic phase and solid potassium sulphate is discharged from the reactor as an aqueous slurry. This is filtered, and the filter cake is washed with water before being dried. The wash water is used for diluting the sulphuric acid feed, so any potassium sulphate that dissolves in it is returned to the process.

The rich organic phase is washed with water in a counter-current contacting device. All the acidity is removed and the barren solvent is returned to the reactor. The aqueous hydrochloric acid is saturated with solvent, and this is recovered by stripping with live steam under vacuum. The recovered solvent is returned to the extraction circuit.

Consumptions and product quality

Materials and utilities consumption (per tonne K_2SO_4 product)

KCl	0.85 tonne
H_2SO_4	0.64 tonne
Electricity	38 kWh
Fuel oil (10,000kcal/kg)	24 kg
Steam (7 bar sat.)	112 kg
Process water	3.2 m^3
Cooling water	5 m^3
Solvent make-up	10 kg

Product quality

K_2SO_4	96%
Cl^-	<0.5%

Fig. 5: Block Flow Diagram of Israel Chemicals Experimental Potassium Sulphate Process

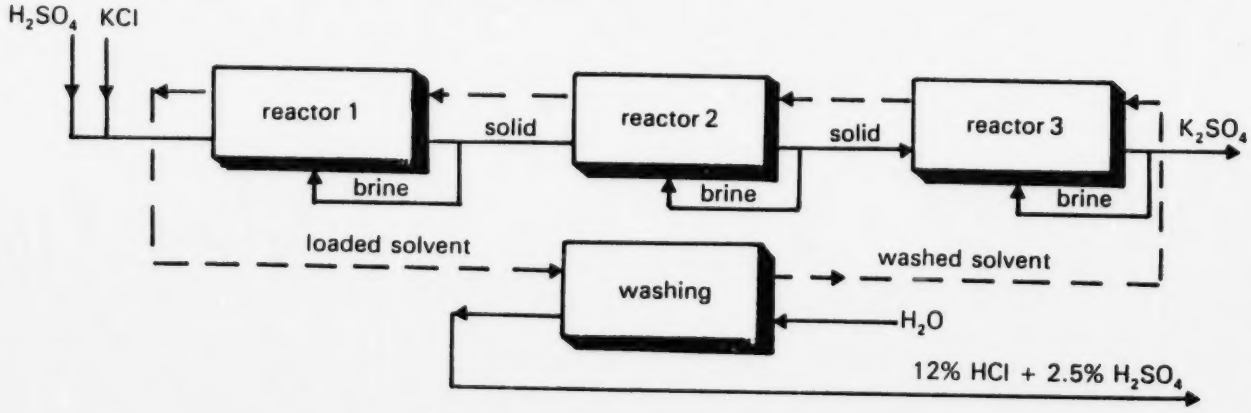
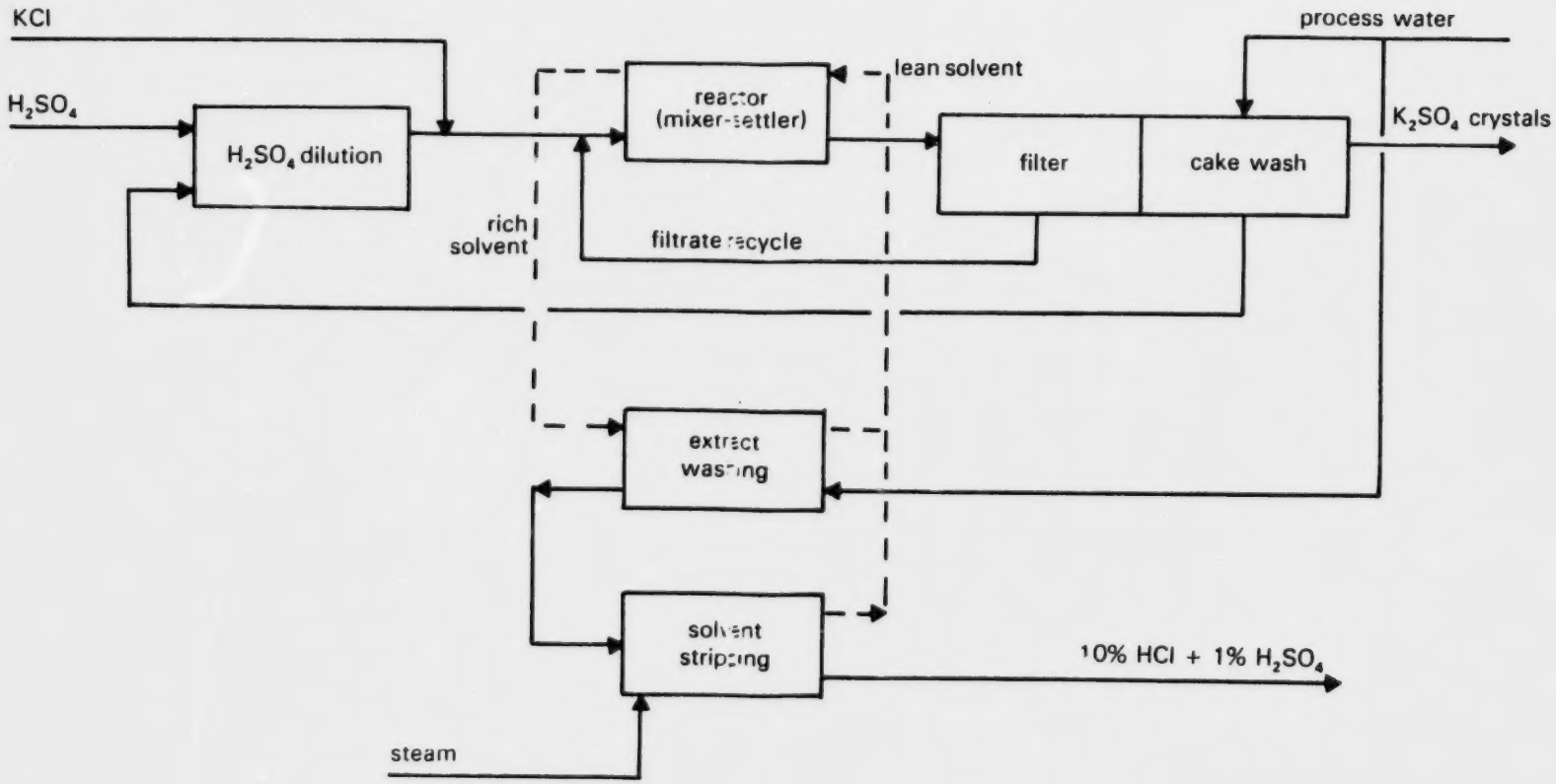


Fig. 6: Apparent Process Arrangement of Israel Chemicals Pilot Potassium Sulphate Plant



THE PENNZOIL PROCESS

Whereas the Israel Chemicals process uses solvent extraction to remove all the hydrogen chloride liberated in the reaction of potassium chloride and sulphuric acid, Pennzoil Co. uses a two-stage system. In the first stage, as in the Chisso process, the reaction proceeds as far as potassium hydrogen sulphate, $KHSO_4$, the hydrogen chloride being displaced by heat. Pennzoil's interest is mainly in using the potassium bisulphate in the production of monopotassium phosphate rather than proceeding all the way to the neutral sulphate; nevertheless, potassium sulphate can be produced in a second stage using solvent extraction to remove not hydrogen chloride, as in the Israel Chemicals process, but sulphuric acid, as will be explained below. The advantage of this system is that the hydrogen chloride from the bisulphate stage can be produced in anhydrous form or as concentrated hydrochloric acid. The highest temperature involved is $115^{o}C$, so acid-resistant plastics can be used in the construction of the plant.

The bisulphate stage has been demonstrated in a semi-commercial installation at Hanford, California.

Outline description

A flow diagram of the bisulphate process is shown in Fig. 7. Potassium chloride and sulphuric acid are introduced into a mixing tank with recycle brine. The solution then passes into an evaporator operating at $115^{o}C$, which displaces hydrogen chloride, before entering a crystallizer, in which it is cooled so as to promote crystallization of the potassium bisulphate. The crystals are then separated from the supernatant liquor and washed on a filter, and the combined washings and supernatant are recyled to the mix tank. Hydrogen chloride in the combined vapours from the mix tank, the HCl evaporator and the crystallizer is either dried or absorbed in water.

Figure 8 is a flow diagram of the potassium sulphate stage. In contrast to the Israel Chemicals process, effectively no chloride is present in this stage, as it is fed with solid potassium bisulphate separated from the reaction liquor in the bisulphate stage. This bisulphate is redissolved in staurated potassium sulphate mother liquor recycled from later in the process and is then subjected to countercurrent extraction with a hydrophilic solvent such as butyl alcohol. Bisulphate ions in aqueous solution are in equilibrium with hydrogen ions and neutral sulphate ions (reaction 5).

$$HSO_4^- \rightleftharpoons H^+ + SO_4^= \qquad (5)$$

These same ions are in equilibrium (in different proportions) in aqueous solutions of sulphuric acid. Therefore it is actually possible to derive sulphuric acid from a bisulphate solution, even though formally there appears to be none there. This is what happens in the first solvent extraction stage. Sulphuric acid and, to some extent, water are soluble in butyl alcohol, and by continuously solvent-stripping sulphuric acid from the bisulphate solution, it is possible to shift the equilibrium in reaction 5 in favour of the sulphate ion. Potassium ions, however, do not pass to any significant extent into the butyl alcohol, and the concentration of them and of neutral sulphate ions in the aqueous phase exceeds the solubility of potassium sulphate, which therefore starts to crystallize. So what is happening, in effect, is shown in equation 6.

$$2KHSO_4 \longrightarrow K_2SO_4 + H_2SO_4 \qquad (6)$$

The aqueous slurry leaving the extraction unit is cooled in a crystallizer to ensure that the maximum amount of solid potassium sulphate will be formed. This is then filtered and washed with water, to remove as much as possible of the sulphuric acid and the traces of butyl alcohol remaining from the aqueous phase, before being dried, if required. The mother liquor and washings are recycled to the potassium bisulphate dissolver.

The alcoholic extract of sulphuric acid, meanwhile, is contacted with a second, hydrophobic, solvent, which is normally a hydrocarbon such as pentane or cyclohexane, in a mixer-settler. This absorbs the butyl alcohol but rejects both the water (which may amount to about 10% of the alcoholic extract) and its sulphuric acid content. Thus a dilute aqueous sulphuric acid stream, containing a minor amount (say 5%) of butyl alcohol, is drawn off from the bottom of the mixer-settler. If it is desired to separate the butyl alcohol from the dilute sulphuric acid, this has to be done by azeotropic distillation or some other means. The organic phase passes from the mixer-settler to a distillation column in which the two components are separated and recycled, the hydrocarbon to the mixer-settler and the alcohol to the countercurrent extraction unit.

Information is not presently available on the granulometry of the product, nor is it known whether this process has graduated beyond the stage of small-scale development.

Utilities consumption

Information is very incomplete. A fuel consumption of 6.8 million Btu per ton and an electricity requirement of 200 kWh per ton have been mentioned.

Fig. 7: Pennzoil Potassium Bisulphate Process

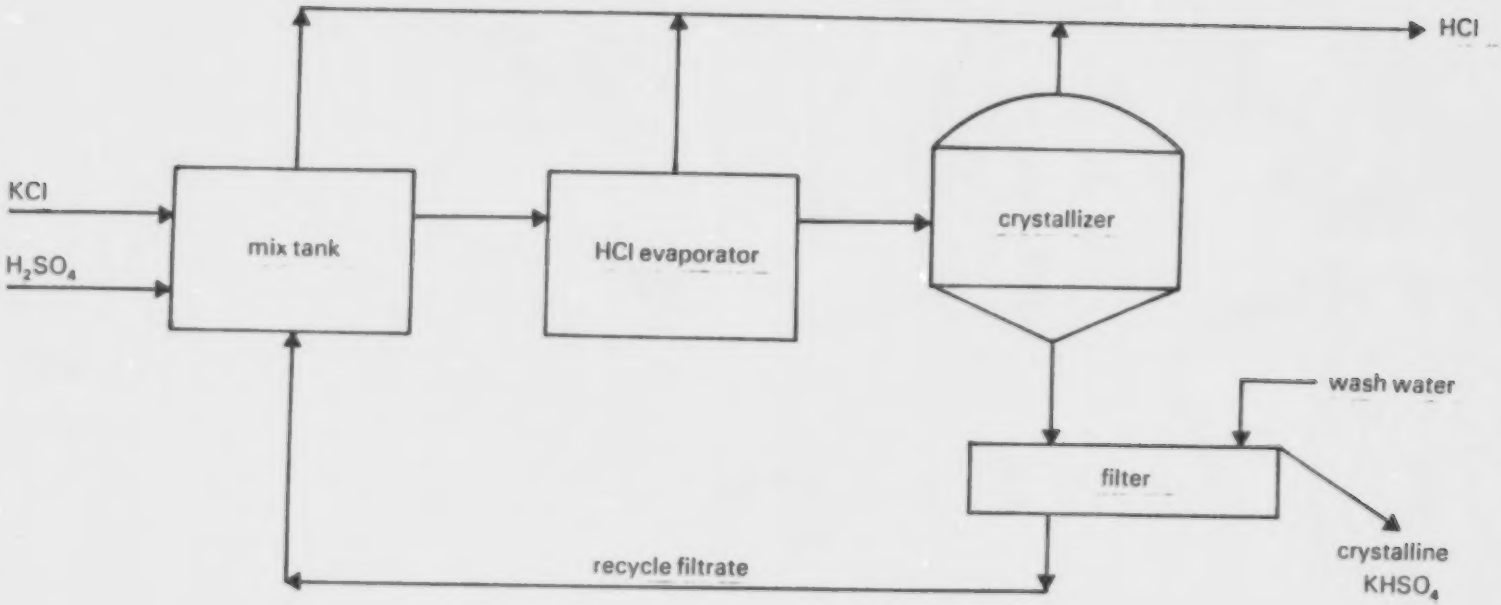
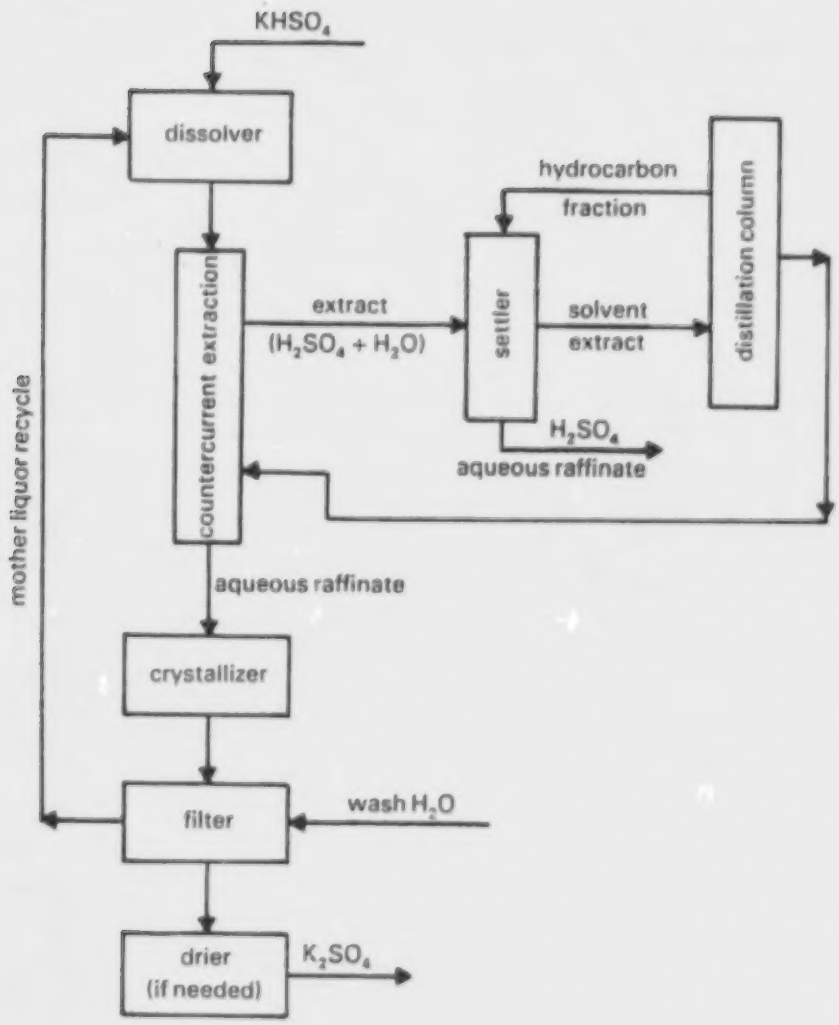


Fig. 8: Pennzoil Potassium Sulphate Process



PROCESSES USING OTHER SULPHATES

MAGNESIUM SULPHATE-BASED PROCESSES

In certain circumstances kieserite (magnesium sulphate) is used as the source of sulphate for producing potassium sulphate from potassium chloride because it occurs in association with the potash deposit and is mined at the same site. Therefore potassium sulphate can be produced at the minehead without any need to bring in other raw materials from outside. This is the basis of the Kali und Salz process, used at its Hattorf mine in West Germany.

KALI UND SALZ PROCESS

Initial preparation

The run-of-mine ore from the Hattorf mine comprises about 15% sylvite (KCl), 5% carnallite ($KCl.MgCl_2.6H_2O$), 23-25% kieserite ($MgSO_4.H_2O$) and 55-57% halite (NaCl). It is subjected initially to hot leaching with a sub-saturated potassium chloride brine, which leaves the sodium chloride and magnesium sulphate as solids. Formerly these were exclusively separated by redissolution and recrystallization of the magnesium sulphate, leaving a sodium chloride brine to be disposed of. Recently the company has installed electrostatic separation facilities to permit dry separation; the solid sodium chloride is stacked, thus avoiding the brine disposal problem.

Outline description

Magnesium sulphate and solid potassium chloride are made to react in a brine medium in an agitated reactor. Potassium sulphate crystallizes out, leaving magnesium chloride in solution. The potassium sulphate is separated and washed on a rotary vacuum filter and is dried to a moisture content of 0.5% in a natural gas-fired dryer. The magnesium chloride solution is disposed of into deep wells.

Product quality

K_2O	50%
Cl^-	1%

CALCIUM SULPHATE AS THE PRIMARY SULPHATE SOURCE

Calcium sulphate is attractive as a source of sulphate for producing potassium sulphate from potassium chloride because it is widely available as an industrial waste from phosphoric acid manufacture and from lime-based flue gas desulphurization systems or, failing that, as a cheap mined raw material. The complicating factor, however, is that from an aqueous solution containing potassium, calcium, sulphate and chloride ions the species that is precipitated is a double salt of potassium sulphate and calcium sulphate. According to the proportions of potassium and calcium in the solution, this may be syngenite, $K_2SO_4.CaSO_4.H_2O$, or 'penta salt', $K_2SO_4.5CaSO_4.H_2O$. There are two basic strategies that can be adopted for dealing with this problem. One is to use an additive to inhibit double salt formation and allow potassium sulphate to crystallize instead. The other is to separate the syngenite or penta salt and decompose it in a separate stage.

THE IMI PROCESS

The process under trial by the Israel Chemicals subsidiary, IMI Institute for Research and Development, is an example of the first type. It is based on the observation that, if ammonia is added to the system, the solubility of K_2SO_4 decreases by a larger margin than that of the double salt species. By the time the concentration of ammonia reaches 35% potassium sulphate is the least soluble salt in the system.

The process is being developed to operate on waste phosphogypsum from local phosphoric acid production. So far it has been tested in a 10-kg/h continuous pilot plant.

Outline description

Stoichiometric quantities of potassium chloride and gypsum are made to react in 40% ammonia solution. To keep ammonia losses from this rather concentrated solution to a minimum without the need for operating under pressure, the temperature has to be kept at $-5^{\circ}C$. A residence time of several hours is needed to attain an eventual conversion of about 95%. The limiting factor is the initial solubility of the gypsum, so the rate of reaction is enhanced by anything that encourages dissolution of the gypsum. Therefore, it is inversely proportional to the size of the gypsum crystals and directly proportional to the ratio of solution to gypsum. Common contaminants of the phosphogypsum (phosphate, fluoride, silica) do not appear to have much effect on the reaction, but they remain in the product, so the purity of the product is a direct function of the purity of the phosphogypsum used.

After reaction the potassium sulphate is separated by filtration, washed with ammonia solution at -5°C and dried (Fig. 10). Ammonia is recovered from the plant liquors by distillation and is recycled along with the vapours from the drying stage. The technology for handling the ammonia is well established, as it has long been used in the Solvay process for the production of sodium carbonate. Thus it is certain that losses can be kept low.

Preliminary estimates indicate that, for a 150,000-t/a plant under conditions prevailing in Israel, the capital cost of a plant would be less than half that of a corresponding Mannheim plant and its energy consumption about 30% lower.

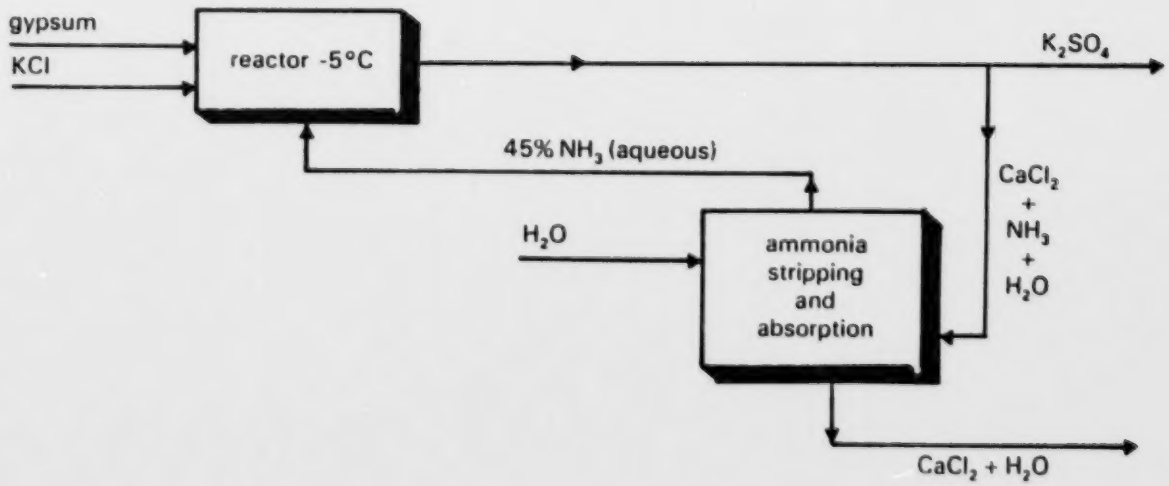
Product quality

K_2O content	48-50 wt-%
Cl^-	less than 0.5 wt-%

The crystals are small and will require agglomeration if the material is to be marketed as a bulk commodity.

Work has also been conducted on a bench scale on this type of process at the **University of Nottingham**, England. A proposal was reported a few years ago for avoiding the need for refrigeration by using an aqueous mixture of ammonia and hydrazine, but the latter chemical is neither widely available nor cheap, and some of the cost advantage of running at ambient temperature would therefore be lost.

Fig. 10: Potassium Sulphate from Gypsum



SODIUM SULPHATE-BASED PROCESSES

THE PCS GLASERITE PROCESS

In an attempt to diversify its production operations from the sole product, muriate of potash, Potash Corporation of Saskatchewan (PCS) has been developing a process for the manufacture of potassium sulphate.

None of the sulphate sources on which the processes described previously operate is readily to hand in Saskatchewan, and to freight one in would be too expensive. So PCS turned its attention to natural sodium sulphate, of which substantial deposits are associated with its potash deposits.

Being considerably less soluble than either sodium or potassium sulphate, glaserite - a double sulphate of potassium and sodium corresponding to the formula $3K_2SO_4.Na_2SO_4$ - will crystallize from any solution containing appreciable concentrations of sodium, potassium and sulphate ions. The precipitated double salt can then be decomposed into sodium chloride and potassium sulphate by treatment with a saturated potassium chloride brine.

$$4Na_2SO_4 + 6KCl \rightarrow 3K_2SO_4.Na_2SO_4 + 6NaCl \quad (17)$$
$$3K_2SO_4.Na_2SO_4 + 2KCl \rightarrow 4K_2SO_4 + 2NaCl \quad (18)$$

The principle of this process has been known for many years, being described in a U.S. patent specification published in 1933. Further work was done in Canada in the 1960s, and the PCS development was therefore more in the nature of a check on earlier work rather than a breaking of new ground.

Successful pilot plant trials have been carried out on a scale of 450 kg/h, using a variety of feeds including various grades of salt cake (anhydrous sodium sulphate), natural Glauber's salt ($Na_2SO_4.10H_2O$), potassium chloride dryer dust and white crystalline potassium chloride. The process has been adopted in a 30,000-t/a demonstration plant which has just been completed at the company's Cory Division site in Saskatchewan. A full-scale (200,000 t/a) plant is also being discussed.

Outline description

Figure 11 is a flow diagram of the process used in the pilot trials.

Potassium chloride and sodium sulphate are added to successive agitated reaction tanks at the start of a series of five tanks, through which a complex brine is recycled from a later stage in the process. The composition of this brine corresponds to the triple point between potassium chloride, sodium sulphate and glaserite on a Janecke phase

diagram (Fig. 12). It contains 18 moles of water per mole of salts. The first-stage reaction slurry density - dictated by mass balance considerations - is 10-15% solids.

After thorough agitation in the remaining reactors of the series, practically all of the sulphate feed has been converted to glaserite, and this is separated out by filtration or centrifuging. It is then introduced into the second reactor chain, where it encounters a saturated brine of potassium chloride. This has the effect of decomposing the glaserite and precipitating potassium sulphate, which is subsequently removed in a centrifuge. Sodium chloride formed in each stage is kept in solution by adding just enough water to prevent it from crystallizing.

The first-stage exit brine cannot be directly recycled on account of its composition, and some sulphate and potassium values are in consequence lost from the process. However, several recovery circuits have been studied which ought to enable at least 90% of the feed material to be recovered.

Cautions

The results of this work by PCS have revealed several design and operating constraints.

A substantial residence time (up to 4 hours) is required for the reactions to reach 90% completion, which is the minimum required for industrial implementation. Intensive agitation of the reaction media is also required.

Overall yield is rather low - somewhat less than 60% in terms of potassium, about 80% in terms of sulphate - unless the brine from the first stage is reprocessed to allow its potassium and sulphate content to be recycled.

Product purity appears to be acceptable (up to 97.8%) provided that insoluble impurities in the raw materials are kept below 1-2%. The chloride content of the product is 1-1.5% but can be reduced, if required, to 0.5% (at the expense of about 5% product loss) by including a simple washing step.

On account of the fine crystal size it is desirable to subject the product to some kind of treatment to increase its particle size. The standard method is compaction. Binding agents are usually required; even so, if the chloride content is low, compaction is difficult and the product is not very durable. PCS has found that the product with 1% or more chloride can be compacted, but with the low-chloride washed product (0.5% Cl^-) better results have been obtained by pan granulation with proprietary binders.

Fig. 11: PCS Glaserite Process – Potassium Sulphate Pilot Flowsheet

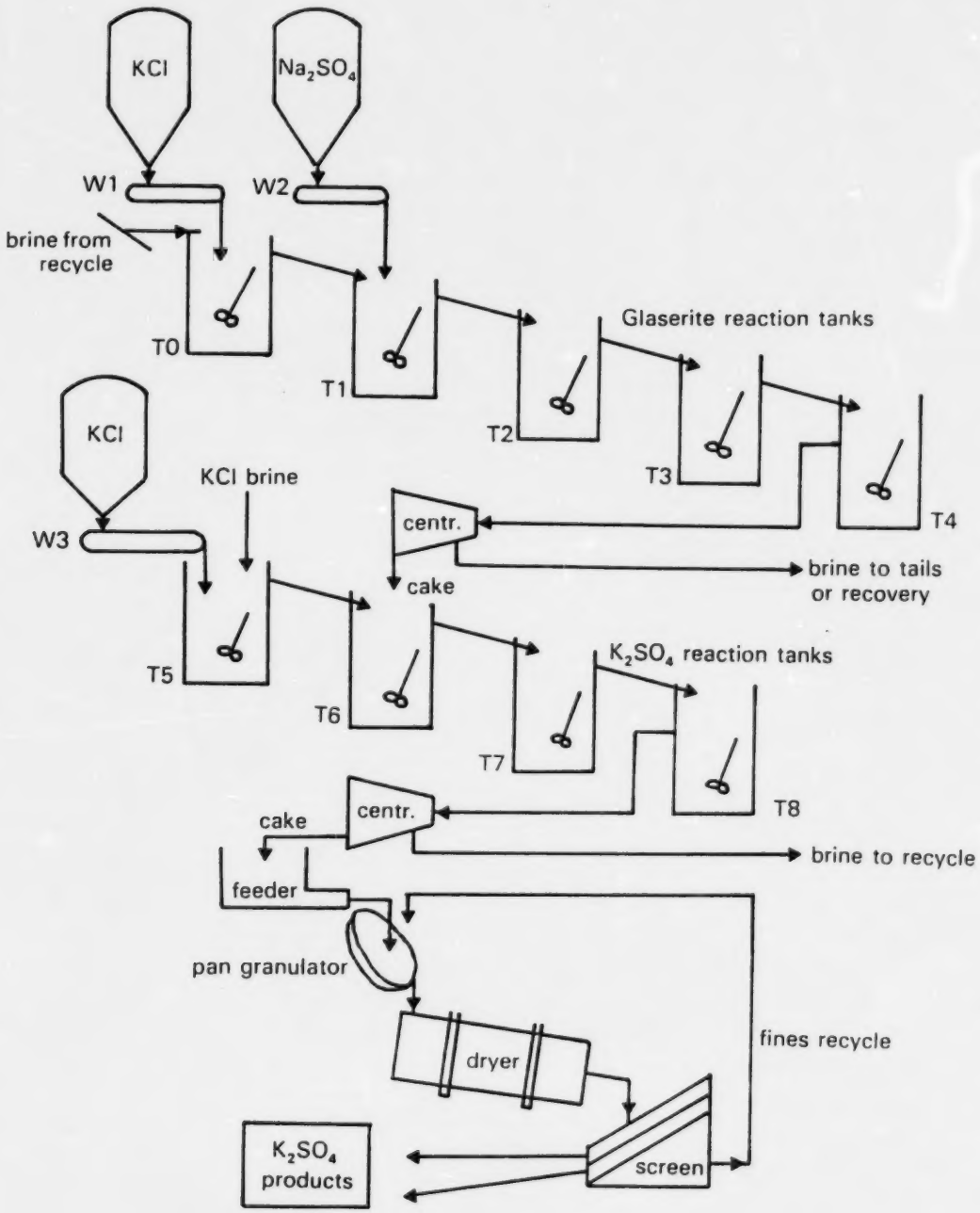
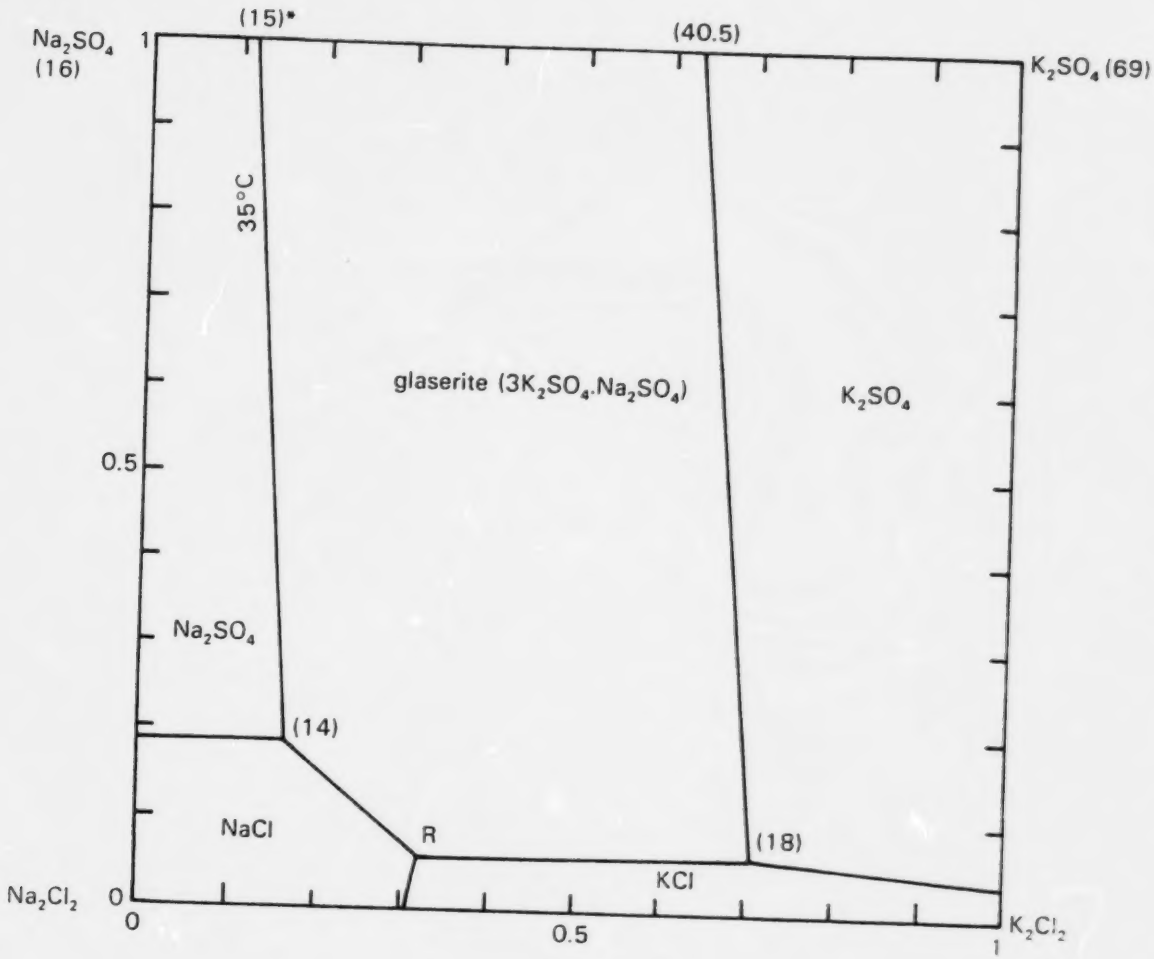


Fig. 12: Janecke Diagram of the System Na_2SO_4-KCl-H_2O



*Numbers in brackets indicate water content of brine in moles/moles of salts

Utilities consumption

Information will not be released by PCS at this time.

THE PRODECO PROCESS

In the Prodeco process solid syngenite is produced, separated and then decomposed. It thus appears at first sight to be a calcium sulphate-based process. However, the principal source of sulphate is, in fact, a soluble sulphate; the calcium values are recycled within the process, so only a small amount of calcium sulphate is needed to compensate for losses in the process. The Prodeco process is equally capable of operating on unbeneficiated sylvinite as it is on potassium chloride. In practice, therefore, the soluble sulphate will normally be sodium sulphate, so that the sodium content can be rejected as sodium chloride along with the halite portion of the sylvinite.

A minor amount of sulphuric acid is also required for make-up purposes.

Outline description

The flowsheet of the process is shown in Fig. 13.

Solid potassium chloride or sylvinite feed is contacted with a recycle solution, A, to be described below, at 80-100°C in a leach system, 1. Potassium chloride is dissolved and solid sodium chloride is precipitated. The sodium chloride is discarded.

The leach solution, B, is next fed into the syngenite preparation unit, 2, where it is allowed to cool to below 40°C while reacting with a calcium sulphate salt and the soluble (sodium) sulphate. As mentioned, the calcium sulphate salt will normally be contained in a recycle stream, C, from a later stage in the process and, depending on the conditions in that part of the process, is either simple calcium sulphate (reaction 1) or 'penta salt', represented by the formula $K_2SO_4.5CaSO_4.H_2O$ (reaction 2). Any make-up will probably be supplied as gypsum, however.

$$2KCl + Na_2SO_4 + CaSO_4 + H_2O \rightarrow CaSO_4.K_2SO_4.H_2O + 2NaCl \qquad (1)$$

$$8KCl + 4Na_2SO_4 + K_2SO_4.5CaSO_4.H_2O + 4H_2O \rightarrow 5(CaSO_4.K_2SO_4.H_2O) + 8NaCl \qquad (2)$$

The slurry of syngenite produced, D, is separated by filtration or centrifuging and washed to remove sodium chloride in unit 3. The mother liquor and washings, E, may be concentrated to remove the wash water in concentrator 4 and recycled to the leach stage as solution A.

In the next stage the solid syngenite, F, is fed with a recycled sulphuric acid-containing solution, G and H, to the syngenite decomposition vessel, 5, which is maintained at elevated temperature (80-100°C). The syngenite decomposes according to reaction 3 or reaction 4.

$$H_2SO_4 + CaSO_4.K_2SO_4.H_2O \rightarrow CaSO_4 + 2KHSO_4 + H_2O \quad (3)$$

$$4H_2SO_4 + 3(CaSO_4.K_2SO_4.H_2O) \rightarrow 3CaSO_4.K_2SO_4.H_2O + 8KHSO_4 + 4H_2O \quad (4)$$

The residence time in this stage is between 30 minutes and 2 hours. Solid calcium sulphate or penta salt or a mixture of the two is separated from the resulting slurry, J, by filtration in a separation unit, 6, and washed in 7 with water. The washed solids constitute the recycle, C, to the syngenite preparation, 2. The wash liquor, N, is utilized in a later stage.

Mother liquor, K, from 6, containing potassium bisulphate, is cooled to 0°C in crystallizer 8. What crystallizes is not potassium bisulphate but a double salt of potassium sulphate and potassium bisulphate, $K_2SO_4.KHSO_4$. The crystal slurry, L, is separated by filtration or other means in 9, the mother liquor, G, being recycled to the syngenite decomposition stage, 5.

The double salt, M, from the preceding stage is slurried in the crystallizer, 10, at 100°C in the combined wash liquors: N from the gypsum wash and O from the later potassium sulphate wash. Liquor O is saturated in potassium sulphate.

Under the conditions in the crystallizer, the double salt decomposes to produce a slurry, P, of crystalline potassium sulphate, which is separated by filtration or centrifuging in 11. The mother liquor, Q, is reconcentrated in 12 and recycled to the syngenite decomposition stage, 5. The crude potassium sulphate crystals, R, are washed in 13 with saturated potassium sulphate solution, S, before being passed as wet potassium sulphate, T, to the drier, 14, from which the product potassium sulphate is obtained.

Commercial status

This process is not yet commercial and has not even been tested on a pilot-plant scale, but it has been successfully demonstrated in laboratory experiments.

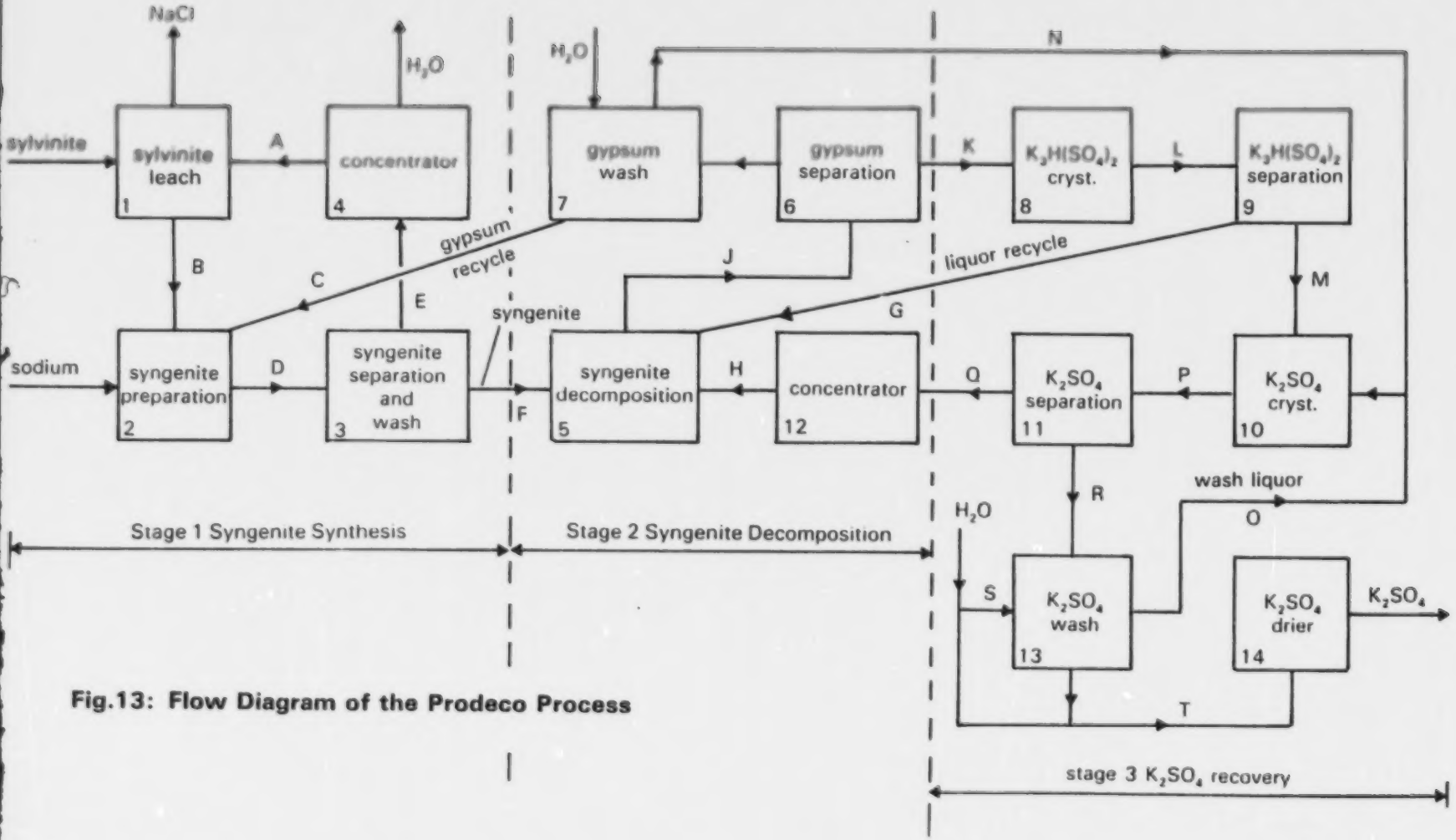


Fig.13: Flow Diagram of the Prodeco Process

TECHNICAL ADVANTAGES AND DISADVANTAGES OF THE ALTERNATIVE PROCESSES

In appraising the processes described in the preceding account, the following factors are clearly of importance.

Availability of the particular sulphate source;
State of development and/or commercialization;
Technical problems;
Outlet(s) for by-product(s);
Production economics.

The last of these is dealt with in greater detail in a later section.

For the purposes of the following comparison the processes are grouped together according to the primary source of sulphate.

PROCESSES USING SULPHURIC ACID AS SULPHATE SOURCE

General

Sulphuric acid is one of the commonest industrial chemicals, but the majority of it is still manufactured in on-site facilities at the location of use. However, especially in eastern Canada, large volumes of sulphuric acid are produced as an involuntary by-product of sulphide ore roasting and smelting operations. There are reasons why - historically - this product has met with a certain amount of resistance in the market, despite its generally low price. One of the most important is that users of sulphuric acid often need the the substantial amount of high-pressure steam by-produced in its manufacture. This, of course, is unavailable if the product is bought in cold from a remote source of production. The value of this steam, and the low cost of elemental sulphur, has tended to provide the economic justification for investing in dedicated on-site sulphuric acid production facilities, especially for large-scale users. At the same time, having captive sulphuric acid production obviates the safety and environmental hazards associated with the transport and unloading of what is, after all, a fairly dangerous chemical.

Recently, however, sulphur has been in tight supply world-wide, and prices on the market have risen to such an extent that by-product acid has become considerably more attractive for industrial users. Since, furthermore, there is still no commercially proven alternative to sulphuric acid production for arresting sulphur dioxide from metal sulphide ore processing operations, more of this by-product acid can be expected to appear on the market as non-ferrous metal smelting operations are progressively brought under the control of environmental regulations, particularly if there is a recovery in that sector of industry.

In general, investment in a dedicated sulphuric acid plant on the scale needed merely to supply a potassium sulphate plant is not nowadays likely to be justified on purely economic grounds. Not only is the amount of sulphuric acid required for such an operation usually too small; also the potassium sulphate plant is not likely to require steam of the grade or in the quantity that the sulphuric acid plant produces. An on-site sulphuric acid plant would therefore only be justified if there were sufficient additional user processes on the same or adjacent sites, or if there were an adequate local market and distribution system, to warrant installing a larger, more economical plant and if a use could be found for the substantial steam credit, for driving process plant machinery or electricity generators and for process heating.

Similarly, any proposal to build a plant which produces hydrogen chloride, whether in the gaseous form or as aqueous hydrochloric acid, must be made only in the light of a very careful evaluation of the possible outlets for this by-product. Hydrochloric acid is traded and distributed as a commercial product, but it is a dangerous material. Facilities for storing, loading, transporting and unloading it must conform to relevant safety regulations and will require special materials of construction, so they are likely to be costly. Preferably this by-product should be used on or in the immediate neighbourhood of the site on which it is produced. The output is unlikely to match the demand of a present-day bulk chemical production plant such as an ethylene dichloride or vinyl chloride monomer unit, and if that is its destination there will have to be an alternative source of chlorine values as well. It is, however, more closely matched to the demands of a typical dicalcium phosphate (animal feed supplement) production unit. The alternative of neutralizing it and disposing of the waste chloride may be discounted on economic and environmental grounds.

So the most likely circumstances in which a process which uses sulphuric acid and produces hydrochloric acid as a by-product will tend to be most favoured are:

(i) in a chemical complex where the hydrogen chloride can be used to make downstream products;

and where

(ii) (a) there is sufficient alternative captive or neighbouring demand for sulphuric acid and steam to warrant running a medium-large-scale sulphuric acid plant, or

(ii) (b) there is a plentiful and reliable source of low-cost by-product sulphuric acid.

Furnace processes

The Mannheim kiln and, to a lesser (but still significant) extent, the Chisso process are both very energy-intensive. On account of the high temperatures, the conditions in the furnace and the associated gas ducting are highly corrosive and, as a result, careful attention is required to materials of construction. Facilities are required for cleaning and, where appropriate, absorbing the hydrogen chloride. Maintenance and energy costs are high. These processes, however, are proven in commercial service.

Only where it can be integrated into an appropriately-scaled existing industrial complex where the required input of sulphuric acid is already available, and where hydrogen chloride is currently being produced voluntarily for captive use or being brought in from outside, does this type of process appear to warrant consideration. Given the uncertain state of the market for chlorine chemicals, there would seem to be little scope for providing new or expanded facilities for using up the hydrogen chloride.

Solvent extraction processes

Israel Chemicals process

As mentioned, a pilot plant is currently under construction. The by-product from this process is a dilute, impure aqueous hydrochloric acid, containing (in relation to its HCl content) a significant proportion of sulphuric acid and an unspecified amount of pentanol solvent. This acid mixture will be used at the pilot plant site in an existing plant which produces phosphoric acid by hydrochloric acidulation of phosphate rock and solvent extraction of the phosphoric acid. This kind of phosphoric acid process is most unusual; it was developed in Israel to exploit hydrochloric acid from salt operations on the Dead Sea and thereby avoid the need to import sulphur (of which Israel has no indigenous supply), which would be required for conventional wet-process phosphoric acid production. The hydrochloric acid output of the Israel Chemicals potassium sulphate process on its own is neither large enough nor concentrated enough to warrant construction of such a phosphoric acid plant, and there would seem to be few other potential uses for such a dilute and impure by-product. The only option would appear to be to neutralize it with lime and dispose of the resultant calcium chloride brine, but this would add to the cost and would, of course, be subject to environmental regulations.

The solvent consumption of this process is a further considerable factor in its disfavour.

Pennzoil process

Because the hydrogen chloride is evolved as a vapour in the bisulphate stage, this process does not suffer from the by-product acid dilution and impurity problem which is the main handicap of the Israel Chemicals process. However, the further conversion of the potassium bisulphate into potassium sulphate appears only to have existed on paper so far, and it is quite elaborate, with two solvent circuits and the need for fractional distillation to separate them.

Butyl alcohols and water are miscible to an appreciable extent, and although solvent losses in the aqueous raffinate from the primary extraction are recovered because the mother liquor is recycled, high losses are likely in the dilute sulphuric acid by-product stream unless it is purified by azeotropic distillation, which will greatly add to the cost. The by-product acid is itself of too low a concentration to have much use or value, and it may well have to be neutralized and disposed of, involving extra cost and possible environmental problems.

PROCESSES USING OTHER SULPHATES

Magnesium sulphate-based processes

Kali und Salz process

As mentioned previously, this process came into being mainly because kieserite is produced from the same mine as potassium chloride ores. It was developed as a simple expedient for making use of a low-value sulphate source that is available on the spot rather than for any particular technical or economic superiority. It would not seem an appropriate choice for a location remote from a source of magnesium sulphate.

Calcium sulphate as primary sulphur source

IMI process

This process would be of prime interest in a location near a natural gypsum mine or a wet-process phosphoric acid plant. In the latter case, careful consideration would have to be given to the tolerable levels in the product of acidic impurities from the phosphogypsum. The calcium chloride brine would have to be worked up to a solid product or disposed of in an environmentally acceptable way.

Sodium sulphate-based processes

PCS Glaserite process

The fact that PCS is committed to building a 30,000-t/a plant indicates a good measure of confidence in the technical operability of the process. It has, as stated, been developed specifically to take advantage of the local availability of sodium sulphate and is inherently incapable of operation on any substitute. The prospective source of sodium sulphate must weigh heavily in any consideration of this process.

A sodium chloride waste brine must be disposed of.

Prodeco process

Although sodium sulphate is the preferred source of sulphate, this process is not limited to using it. The principal technical reason for using it is that it is soluble and therefore reacts quickly. Ammonium sulphate has been specified as an alternative, although it is uncertain whether the process has been as extensively tested with it as it has with sodium sulphate. In this case, the ammonia would leave the process as ammonium chloride brine. This could be treated with lime to recover ammonia, which could be reabsorbed in sulphuric acid to regenerate ammonium sulphate. The primary sulphate source would therefore be sulphuric acid, but the by-product would be a calcium chloride brine, not hydrochloric acid. Ammonia would be required only in sufficient quantities for make-up purposes. As noted previously, too, some calcium sulphate would be required to compensate for losses in the process, but if not to hand as such it could be derived simply by adding some of the lime used for displacing ammonia from the ammonium chloride brine to the ammonia neutralizer.

Though this process has not yet been piloted, it has been successfully demonstrated under laboratory conditions. Modified as suggested to run on ammonium sulphate with ammonia recovery, it is the only process which can feed on sulphuric acid without producing hydrogen chloride or hydrochloric acid as a by-product or waste. Consequently, despite its early state of development, it definitely warrants consideration.

ROBERTSON RESEARCH INTERNATIONAL LIMITED

MEMORANDUM NUMBER RRLS/107

INVESTIGATION OF POTASSIUM SULPHATE PRODUCTION BY THE REACTION OF SULPHUR DIOXIDE, ACETONE, WATER AND POTASSIUM CHLORIDE FOR THE BRITISH SULPHUR CORPORATION

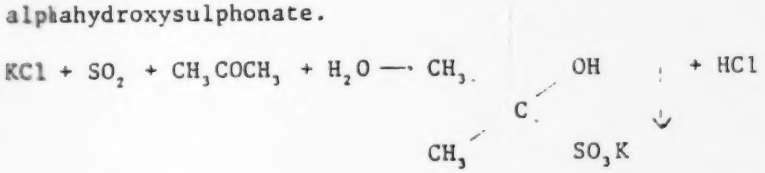
1. INTRODUCTION

The purpose of the investigation was to determine the viability of manufacturing potassium sulphate from potassium chloride using sulphur dioxide, acetone and water. A report by Atlantic Analytical Services Limited entitled "Sulphur dioxide, Acetone, Water in the Preparation of Fertilizers and Potassium Chemicals" claims that such a process route is feasible, but the report does not give any experimental details to back up their claim that the reactions in the process route would proceed.

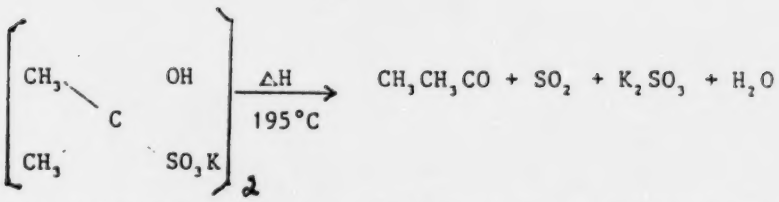
2. PROCESS ROUTE REACTIONS

The process route for the manufacture of potassium sulphate consists of three basic reactions:-

(a) The disolution of potassium chloride in a mixture of sulphur dioxide, acetone and water to produce potassium alphahydroxysulphonate.



(b) Heating the potassium alphahydroxysulphonate to produce potassium sulphite, acetone, water and sulphur dioxide.



(c) Roasting the potassium sulphite to produce potassium sulphate

$$2K_2SO_3 + O_2 \longrightarrow 2K_2SO_4$$

Of these reactions, the last two are well known and can be found in most chemistry text-books. It is the first reaction which is not well known, and was open to question. Consequently a series of laboratory tests were carried out to determine whether a precipitate of potassium alphahydroxysulphonate would be formed when mixtures of SO_2, KCl, water and acetone were shaken together.

3. EXPERIMENTAL WORK

As outlined in the report "Sulphur dioxide, Acetone, Water in the Manufacture of Fertilizers and Potassium Chemicals" the steps of the reaction are as follows:-

1. KCl is purified to remove insolubles by saturating the make-up water with KCl.
2. The solvent (acetone sulphonate; caused by the reaction between SO_2, acetone and H_2O) is mixed with the purified KCl, and the reaction allowed to proceed.

Using this information a series of tests were carried out in which varying amounts of saturated potassium chloride solution were mixed with a SO_2/acetone/water solvent.

4. EXPERIMENTAL DETAILS

750 g of acetone was mixed with 250 g of water. Sulphur dioxide (from a compressed gas cylinder) was passed through the solution until the weight of the solution had increased by 20%. This resulted in a solution which was:

63% Acetone

20% Water

17% SO_2 by weight

A saturated solution of KCl was made by disolving 300 g of KCl in 1000 g of water. Varying amounts of this saturated solution (10, 20, 30, 40 and 50 ml) were then reacted with 100 ml portions of the solvent. A precipitate was formed in each case. The precipitates were filtered and washed with acetone. As the precipitates were being washed it was noted that more precipation was taking place in the filtrate.

An analysis of the precipitate (using standard chemical tests) showed that it was potassium chloride. The addition of acetone to the saturated potassium chloride solution had resulted in potassium chloride being precipitated. This demonstrated that the levels of acetone and water present in the reaction mixture were critical in determining the solubility of KCl.

To confirm this, a saturated solution of KCl was added to acetone. A precipitate of KCl was immediately formed.

Information in the paper regarding the relative solubilities of potassium chloride and potassium hydroxy-sulphonate was, to say the least, sparse. However, it soon became apparent that:

(a) Potassium alphahydroxysulphonate is soluble in water and insoluble in acetone.

(b) The solubility of potassium chloride will depend upon the ratio of acetone to water, - ie. the greater the amount of water present, the greater its solubility.

As the reaction depends upon the precipitation of the sulphonate only, then care will be needed to control the ratio of water/acetone and KCl. Any potassium chloride which is re-precipitated out at this stage will remain unaffected by the later heating stages and remain in the K_2SO_3 product and therefore the K_2SO_4 product.

After this work had been carried out, the Canadian patent number 832,931 entitled "Production of Alkalai Metal Sulphites or Bisulphites" was obtained. This patent, together with US patent number 3,248,278 "Recovering Monovalent Cations from Spent Sulphite Liquor" was taken out by W J Wilson - the author of the Atlantic Analytical Services report. The Canadian patent gave useful experimental details about the reaction. One important aspect of the reaction - which is not immediately apparent from the report - was that the reaction proceeds better at lower temperatures (0°C) and required constant agitation for 24 hours to achieve good yields. Also, lower concentrations of the chloride (sodium) were used.

The patent gave results of mixing together NaCl, SO_2, acetone and water for 24 hours at 15°C and 0°C. These tests were reproduced at RRI laboratories using equivalent weights of KCl instead of NaCl.

(i) Canadian Patent 832,931 - Testwork Results

Composition of Reaction Mixture				Temp °C	Yield of Complex Sodium Sulphonate	
ml Acetone	ml Water	g SO_2	g NaCl		g	%
80	20	30	2.38	15	4.50	68.3
70	30	30	3.50	15	5.40	55.7
60	40	30	4.26	15	3.74	31.6
80	20	30	2.67	0	6.68	90.4
70	30	30	4.05	0	9.99	89.0
60	40	30	4.69	0	10.85	83.5

(ii) RRI Results (KCl used = 1.273 times NaCl weight used in (i))

Composition of Reaction Mixture				Temp °C	Yield of Complex Potassium Sulphonate	
ml Acetone	ml Water	g SO_2	g KCl		g	%
80	20	30	3.03	15	0.39	5.4
70	30	30	4.46	15	0.00	0.0
60	40	30	5.43	15	0.00	0.0
80	20	30	3.40	0	6.37	78.4
70	30	30	5.16	0	8.00	64.9
60	40	30	5.97	0	5.18	36.3

After the insoluble sulphonate had been filtered, acetone was added to the filtrate and further precipitation of the sulphonate occurred.

This gave the following total yields of potassium sulphonate:-

Composition of Reaction Mixture				Temp °C	Yield of Complex Potassium Sulphonate	
ml Acetone	ml Water	g SO_2	g KCl		g	%
80	20	30	3.03	15	4.96	68.5
70	30	30	4.46	15	5.41	50.8
60	40	30	5.43	15	6.45	49.7
80	20	30	3.40	0	6.94	85.4
70	30	30	5.16	0	9.34	75.8
60	40	30	5.97	0	9.08	63.7

The precipitates were examined using infra-red spectroscopy techniques. They were found to consist of potassium hydroxysulphonate. When the precipitates were heated to 100°C they experienced a loss in weight consistant with the reaction

$CH_3.CH_3.C.SO_3.KOH \longrightarrow$ acetone + $KHSO_3$

when heated to 200°C the hydroxysulphonates experienced a loss in weight consistant with the reaction

$CH_3.CH_3.C.SO_3.KOH \longrightarrow$ acetone + $\frac{1}{2}K_2SO_3$ + $\frac{1}{2}H_2O$ + SO_2

The residue remaining was examined by infra-red spectroscopy and was found to be potassium sulphite.

Conversion of potassium sulphite to potassium sulphate.

Data concerning the conversion of potassium sulphite to potassium sulphate is scarce. The reaction is exothermic but requires heat (~ 450°C) to make the reaction proceed quickly

$K_2SO_3 + \frac{1}{2}O_2 \longrightarrow K_2SO_4$

This would obviously be a major energy requirement - something not mentioned in the A.A.S. report. Laboratory testwork indicated that the heat capacity of potassium sulphite is 2.9J/g/°C. Therefore roasting 1 tonne of K_2SO_3

to produce 1.1 tonnes of K_2SO_4 would require:-

$\sim 2.9 \times 10^6 \times (450-25)$ J/tonne

$\sim 1.233 \times 10^9$ J/tonne

= 294,976 kcal/tonne

5. DISCUSSION AND CONCLUSIONS

The testwork has indicated that the basic chemical reactions related to the production of potassium sulphite using acetone, SO_2, and water - as described in the Atlantic Analytical Services report - do proceed.

The report, however, does not make clear that:

(i) Good yields of the complex sulphonates are only formed at 0°C.

(ii) Under certain conditions the sulphonate is soluble in water and care is needed to accurately monitor the levels of acetone and water in order to achieve maximum precipitation of the sulphonate.

(iii) Generally, RRI yields were lower than those achieved in the patent. In some cases, precipitation only occurred when the acetone concentration of the reaction solution was increased. When this was done the sulphonate was immediately precipitated.

The reaction depends on the stronger dissociation constant of acetone, sulphur dioxide and water over water and sulphur dioxide mixtures thus allowing the reaction to proceed with the formation of hydrochloric acid. Obviously HCl has to be removed from the system and cannot be allowed to become too concentrated if yields are to be maximised.

A second disadvantage occurs with the volume of acetone necessary to achieve precipitation of the sulphonate whilst at the same time containing sufficient water to prevent KCl precipitation. Typically it can be estimated that

four times the volume of acetone will be required over the volume of KCl solution which will lead to large plant capacities. Furthermore, the reaction time quoted of 24 hours will result in additional reagent and plant requirements especially considering the low temperatures necessary for the reaction.

The obvious further drawback of the process route is that the sulphite is formed and not the sulphate. Conversion of sulphite to sulphate requires high temperatures and a large energy input - comparable to that of the Mannheim process. If elevated temperatures are required to produce K_2SO_4 then the process route reference must lie with a process which is already well established.

The A.A.S. report does not give an unbiased account of the process route for the manufacture of potassium sulphate. This is no doubt due to the fact that the report's author has taken out the patents for the reactions mentioned in the report. The basic reactions do proceed as stated and the process route does present some very interesting opportunities. However, much more work would be required on the process route before going to a pilot stage or full scale production. Specifically, more information is required about the solubilities of the sulphonate, the reaction kinetics of the SO_2-water-acetone-KCl reaction, and the reaction kinetics of the sulphite to sulphate reaction.

TECHNICAL CONCLUSIONS

To date, except where special circumstances favour the use of magnesium sulphate, furnace processes are the only fully proven route from potassium chloride to potassium sulphate. But they suffer from a number of inherent technical and economic disadvantages, and they yield a by-product which is difficult to store and must be marketed or used in other processes.

The solvent extraction processes suffer from high losses of relatively expensive solvents. They also produce troublesome dilute acid side-streams and are not yet proven in commercial operation.

Calcium sulphate merits consideration as a low-cost sulphate source but it must be remembered that the IMI process and similar processes are still in an early stage of development.

Alone among the processes examined, the Prodeco process - modified to run on ammonium sulphate rather than sodium sulphate - appears, at least on paper, to offer an elegant route from sulphuric acid and potassium chloride to potassium sulphate which does not involve the generation and the need to handle hydrogen chloride gas or hydrochloric acid solutions. Despite its early stage of development, therefore, it could be highly worth while to examine this process in detail under a secrecy agreement between the interested parties.

PRODUCTION COSTS

Introduction

The purpose of this preliminary evaluation of production costs is to give an "order of magnitude" indication of the costs of various processes, based on information which is available.

Only three processes (Mannheim, Chisso and Kali und Salz) are fully commercial and details on the other processes of lesser commercial status are in the main either unknown or undisclosable. The Consultants have collected and summarised as much information as possible on process unit consumptions, where they are known and disclosed.

Furthermore, some of the processes included in this review are site-specific to take advantage of a particular circumstance concerning the availability of a sulphate raw material and therefore it is not totally relevant to generalise the costs of these processes for East Canadian conditions or New Brunswick conditions specifically.

The following summary provides the basis for the assumptions used in this review.

Raw Materials

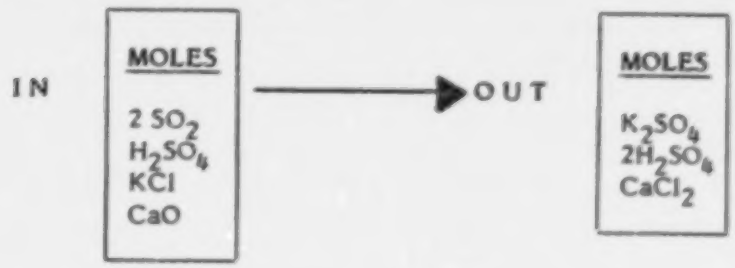
It has been assumed that potash (KCl) would be made available for a price in the range of $50/tonne. Were it possible to find a combination in Canada of an ore containing KCl and $MgSO_4$ similar to that used by Kali und Salz in West Germany then it is assumed it would be available at about $6/tonne (10% K_2O) or at any rate less than $10/tonne.

In the event that a mineral resource of magnesium sulphate is found, then it is assumed that crude $MgSO_4$ from ore would be made available at about $40/tonne (compared to its commercial price of $175/tonne approx). Similarly, it is assumed that the PCS/Glaserite process is conceived around a brine/evaporite deposit of sodium sulphate and not on the use of commercial material; it has therefore been assumed that crude sodium sulphate would be made available at any potassium sulphate project for $40/tonne (compared to the commercial price of pure material about $90/tonne). Calcium sulphate in the form of gypsum is available in large tonnages from phosphoric acid facilities where it must otherwise be disposed to waste; it could therefore be made available to a potassium sulphate facility adjacent to a phosphoric acid site for effectively zero cost ($\pm$$5/tonne).

In East Canadian conditions sulphuric acid is assumed to be available at a favourable location for $20/tonne.

Information in the Consultants' possession on the EMR process indicates that the cost of presenting SO_2 from flue gas to the potassium sulphate conversion step is about \$43/tonne SO_2 (\$73.93 less \$30.60 for sulphuric acid cost which is later recovered). In the Consultants estimation SO_2 would be made available at effectively zero cost adjacent to an East Canadian smelter (±\$5/tonne) consistent with the prevailing price of merchant sulphuric acid already mentioned; subjected to magnesium oxide treatment in order to make it available to the EMR scheme, it is estimated that SO_2 from this source could be made available to the process for about \$25-30.

For the purposes of the economic evaluation of the EMR process the Consultants have assumed that the following is a representative approximation of the overall flow of materials through the process.



The specific consumptions of raw materials has been assessed on this basis and is at variance with the information provided to us under secrecy agreement, which we believe to be in error.

The costs of other materials and utilities used in this report are believed to be typical of East Canadian conditions.

By products

For all processes based on sulphuric acid (except Prodeco), it is necessary to identify an outlet for substantial quantities of hydrochloric acid (of varying concentration). The Prodeco process gives calcium chloride by product in this case.

In all cases except ammonium chloride, chloride by-products ($MgCl_2$ $CaCl_2$, $NaCl_2$ etc.) are assumed to have no realisable value and require disposal. The EMR submission in contrast assumes optimistically that $CaCl_2$ can be sold at \$207/tonne; in North America the tonnage price of $CaCl_2$ is \$90/tonne for basic grades, but the most likely disposal is to waste (as is the case with calcium chloride by-product from soda-ash manufacture).

Ammonium chloride, which is produced as a by-product in one variation of the Prodeco process (with ammonium sulphate as a sulphate source), has a value as a fertilizer material. The product is traded in the Far East and South America as a fertilizer (derived from a variation of the ammonia/soda ash process). However, in East Canada it is to be expected that its value would be low and its use would be confined to blending/mixing with other material in compound fertilizer production. In any event, little information is available at this stage on the production economics of the Prodeco process, and the ammonium sulphate variation has not been costed in this exercise.

Semi-variable and Fixed Costs

The exercise which follows derives notional Net Cash Costs of Production for all processes under review. These costs are net of credits but make no allowance for semi-variable and fixed costs such as labour, supervision, management, overhead and capital related charges for interest depreciation, return on capital.

Since new commercial operations for the production of potassium sulphate have not been built for many years, information on capital costs is limited. Where possible comments on capital costs, capital charges and labour costs are inlcuded and their effect on total production costs of potassium sulphate are noted.

TABLE 1

SUMMARY PROCESS INFORMATION AND UNIT CONSUMPTIONS

PROCESS NAME	MANNHEIM	CHISSO	ISRAEL CHEMICAL	PENNZOIL	KALI UND SALZ	KALI UND SALZ	IMI
Type of Process	furnace volatilization	furnace volatilization	solvent extraction (pentanol)	volatilization/ solvent extraction (butyl alchol pentane/ cyclohexane)	fractional crystallization	(using separate RMS)	fractional crystallization (with ammonia
Feedstock, options	H_2SO_4	H_2SO_4	H_2SO_4	H_2SO_4	KCl, $MgSO_4$ } ore		$CaSO_4$
Commerical Status	fully commercial	fully commercial	pilot operation under study	partly demonstrated on semi-commercial scale	fully commercial		pilot tested at 10 kg/hr
Product Purity	50% K_2O 3% Cl 4% H_2SO_4	50% K_2O 3% Cl 0.2% H_2SO_4	50% + K_2O 0.5% Cl	unstated	50% K_2O 1% Cl		48-50% K_2O 0.5% Cl
By-product(s) for sale	HCl 35% wt	H_2SO_4 HCl 35% wt	HCl 20% wt	anh. HCl			
for disposal					$MgCl_2$		$CaCl_2$
Unit Consumption/t K_2SO_4							
POTASH							
KCl, t	0.850	0.865	0.850	0.85 e		0.85 e	0.85 e
crude potash ore 10% K_2O					10.3		

TABLE I (Cont/d..)

PROCESS NAME	MANNHEIM	CHISSO	ISRAEL CHEMICAL	PENNZOIL	KALI UND SALZ	KALI UND SALZ	IMI
Type of Process	furnace volatilization	furnace volatilization	solvent extraction (pentanol)	volatilization/ solvent extraction (butyl alchol pentane/ cyclohexane)	fractional crystallization	using separate RMS	fractional crystallization (with ammonia)
Unit Consumption/t (cont/d..)							
SULPHATE							
H_2SO_4 (as 100%)	0.587	.665 (0.555 net)	0.64	0.58 e		0.73 e	
$MgSO_4$							0.83 anh e (1.05 gypsum)
$CaSO_4$							
Na_2SO_4							
SO_2							
OTHER							
HNO_3 t			small q (0.1?)				
lime t		0.025					
ammonia, t		0.015					
solvent (make up kg)			10	10			
PROCESS MATERIALS							
Fuel oil, t	0.11	0.06					
Gas, mm Btu				6.8	0.11		
Process water, m^3	2	1.0					
Cooling water make up m^3		10					
Steam, t		0.02			0.06		
Power, KWh	50	120		200	114		
CREDITS							
HCl as 100%	0.39	.37	0.37 e	0.37 e			
H_2SO_4 as 100%		.11					
Other							
Comments							

TABLE 1 (Cont/d..)

PROCESS NAME	PCS GLASERITE	PRODECO	PRITCHARD FRAXON	UNIT PRICE OF CONSUMPTION	
Type of Process	fractional crystallization	fractional crystallization	ion exchange	$/Unit (Canadian Conditions)	
Feedstock, options	Na_2SO_4 (from brine)	($CaSO_4$) other sulphates e.g. (NH_4), SO_4, H_2SO_4 Na_2SO_4	SO_2 (from smelter)		
Commercial Status	demonstrated at 30,000 t/a	demonstrated at laboratory scale	consultants lab tests did not verify viability of route		
Product Purity	50% + K_2O 1-1.5% Cl	unstated	unstated		
By-product(s) for sale		NH_4Cl	HCl		
for disposal	NaCl	$CaCl_2$			
Unit Consumption/t K_2SO_4					
POTASH					
KCl, t	1.4 e	0.85 e	1.2 e	50	KCl
crude potash ore 10% K_2O				6	KCl ore 10% K_2O
SULPHATE					
H_2SO_4 (as 100%)		0.59 e		20	H_2SO_4
$MgSO_4$				40	$MgSO_4$ (from ore)
$CaSO_4$	1.1 e	OR		0 ±$5	$CaSO_4$ ex phosphoric acid
Na_2SO_4		0.86 e		40	Na_2SO_4 (crude from brine)
SO_2			0.51 e	43.33	SO_2 from flue gas (0.5% SO_2) EMR (net of H_2SO_4)
				$25-30	SO_2 from smelter (10-13% SO_2) EMR
				$0-5	SO_2 from smelter direct (no MgO scrubbing)

TABLE 1 (Cont/d..)

PROCESS NAME	PCS GLASERITE	PRODECO	PRITCHARD FRAXON	UNIT PRICE OF CONSUMPTION	
Type of Process	fractional crystallization	fractional crystallization	ion exchange	$/Unit (Canadian Conditions)	
Unit Consumption/t (Cont/d..)					
OTHER					
HNO_3 t				70	HNO_3
lime t				53	lime
ammonia, t				200	ammonia
solvent (make up kg)					
PROCESS MATERIALS					
Fuel oil, t (40mm BTU)*			0.026*	200	fuel oil
Gas, mm Btu				4.0	gas
Process Water, m^3				0.1	process water
Cooling Water make up m^3				0.05	cooling water
Steam, t				15	steam
Power, KWh				0.04	power
				15/mhr	labour
CREDITS					
HCl as 100%					
H_2SO_4 as 100%				70	HCl
Other				(90	$CaCl_2$)
Comments	60% efficiency K 80% efficiency SO_4		overall 72% claimed		

NOTES TO BE TAKEN IN CONJUNCTION WITH RIGHT HAND COLUMN OF TABLE I

There are three scenarios for SO_2 supply, with different input costs.

1. SO_2 supplied from a 0.5% stream (e.g. flue gas) by magnesium oxide scrubbing and regeneration. Cost according to EMR process report $43.33 per ton SO_2 NET

2. SO_2 supplied from a smelter (at 10-13%) and made available by magnesium oxide scrubbing and regeneration (i.e. as for the EMR Process). Cost according to EMR (on a notational estimate by BSC) is $25-30 per tonne SO_2.

3. SO_2 supplied from smelter (at 10-13% SO_2) and made directly available (e.g. as for the Pritchard Fraxon Process). Cost $0 to plus minus 5 at smelter location only.

TABLE 2

NOTIONAL PRODUCTION COSTS AND BREAKDOWN
($/tonne K_2SO_4)

PROCESS NAME	MANNHEIM	CHISSO	ISRAEL CHEMICAL	PENNZOIL	KALI UND SALZ	KALI UND SALZ	EMR
Unit Consumption/t K_2SO_4							
POTASH							
KCl, t	42.5	43.25	42.5	42.5		42.5	47.5
potash ore (10% K_2O)					61.8		
SULPHATE							
H_2SO_4 (as 100%)	11.74	11.10 (net)	12.8	11.6			11.4
$MgSO_4$						29.2	
$CaSO_4$							
Na_2SO_4							32.06
SO_2							
OTHER							
HNO_3			7.0				
lime		1.33					18.55
ammonia		3.00					
solvent (make up kg)			say 10	say 10			
PROCESS MATERIALS							
Fuel oil	22.00	12.00					
Gas				27.2	0.44		5.88
Process Water	0.2	0.1					
Cooling Water		0.5	say 20				0.53
Steam		0.3			0.90		27.60
Power	2.00	4.8		8.0	4.56		16.60
GROSS CASH COSTS OF PRODN.	78.44	76.38	92.3	99.3	67.7	71.7	160.12
CREDITS							
HCl as 100%	27.30	25.90	25.90	25.90			
H_2SO_4 as 100%							22.8
Other							
NET CASH COSTS OF PRODN.	51.14	50.48	66.4	73.4	67.7	71.7	137.32
Labour & Supervision @ 2mhr/tonne	30	30	30	30	30	30	30
Capital Costs	Capital Cost c.a. $8 million for 30,000 t/a				Investment $100 million for 440,000 t/a		
Capital Charges @ 20% per annum (i.e. no return on capital)	53	say 50			45.46	say 45	say 50
TOTAL NOTIONAL PRODN. COSTS	134.14	130.48			143.16	146.7	217.32

TABLE 2 (Cont/d..)

PROCESS NAME	PCS GLASERITE	PRODECO	PRITCHARD FRAXON	UNIT PRICE OF CONSUMPTION	
				$/Unit (Canadian Conditions)	
Unit Consumptions/t K_2SO_4					
POTASH					
KCl, t	70.0	62.5	60	50	KCl
potash ore (10% K_2O)				6	potash ore 10%
SULPHATE					
H_2SO_4 (as 100%)				20	H_2SO_4
$MgSO_4$				40	$MgSO_4$
$CaSO_4$				15	$CaSO_4$
Na_2SO_4	80.0	38.0		40	Na_2SO_4
SO_2			12.75	43.33	SO_2 from flue gas (EMR)
				25	SO_2 from smelter (EMR)
				5	SO_2 from smelter direct
OTHER					
HNO_3				70	HNO_3
lime				53	lime
ammonia				200	ammonia
solvent make up to kg					
PROCESS MATERIALS					
Fuel oil *(40mm BTU/tonne)			5.20*	200	fuel oil
Gas				4.0	gas
Process Water	$20	say $20		0.1	process water
Cooling Water				0.05	cooling water
Steam				15	steam
Power				0.04	power
GROSS CASH COSTS OF PRODN.	134.0	96.9	67.75		
CREDITS					
HCl as 100%				70	HCl
H_2SO_4 as 100%					
Other				(90	$CaCl_2$)
NET CASH COSTS OF PRODN.	134.0	96.9			
Labour & Supervision @ 2 mhr/tonne	30	30		15/mhr	labour
Capital Costs					
Capital Charges @ 20% per annum (i.e. no return on capital)	say 40	say 50			
TOTAL NOTIONAL PRODN. COSTS	204	176.9			

Economic Conclusions

The sales price of potassium sulphate in Canada is assumed to be in the range of $190-200/tonne. There are only three processes which are demonstrated commercially viable.

These are: Mannheim
Chisso
Kali und Salz

From the preliminary economic analysis it would appear that of the non-commercialised processes the EMR process and PCS Glaserite process are not worthy of further consideration unless there is evidence that the preliminary economics presented here can be substantially improved (by effect of raw material costs or semi-variable and fixed costs).

Based on the assumptions made here (and almost no disclosure from the licensor) the Prodeco process does not appear to offer much of a potential profit margin (although this position may change on more detailed investigations); the process does however have other attractions.

Further disclosures and clarifications by process licensors for the chosen processes are required before the Consultants can provide definitive costings and economic assessment.

CONCLUSIONS

Based on a New Brunswick location and bearing in mind the availability (or non-availability) of indigenous raw materials within the Province, the following processes have been eliminated for the reasons given below:-

Mannheim Process: Chisso Process: Israel Chemicals Solvent Extraction Process: Pennzoil Process: Kali und Salz Process: EMR Process: Potash Corporation of Saskatchewan Glaserite Process: Atlantic Analytical Process (Fraxon).

Two processes warrant further consideration and investigation. They are the IMI gypsum Process and the Prodeco Process.

Eliminated Processes

Furnace Processes: Mannheim and Chisso Processes

Both processes are to a greater or lesser extent energy-intensive. Energy costs in the Province are relatively high. In existing furnace plants the by-product hydrogen chloride is utilized, usually within the complex, for the production of dicalcium phosphate for use in animal feed preparations and/or for the production vinyl chloride monomer or similar plastics intermediates (e.g. by EMC at Tessenderlo and Ham).

Presently there is no outlet in New Brunswick for by-product hydrogen chloride either as the gas or as hydrochloric acid. At the initial level of production of potassium sulphate contemplated, i.e. 30,000 tonnes product per annum, the setting up of a dicalcium phosphate plant is not an economic possibility, even allowing that a market would exist for this tonnage of finished product.

The alternative would be to employ the Israel Chemicals phosphoric acid process which is based on hydrochloric acid attack on phosphate rock followed by solvent extraction of the phosphoric acid produced. This process, although commercially viable in an Israel (Mishor Rotem) location, cannot be economically justified in a New Brunswick location in view of (a) the considerable current and future over production within North America of phosphoric acid by standard sulphuric acid attack on phosphate rock and (b) the initally small tonnages of hydrochloric acid available from the envisaged potassium sulphate plant.

Summarizing: the high energy requirement, the severe operating parameters and the complexity of the infrastructure necessary to ensure supplies of raw materials and outlets for the by-products greatly increase the capital investment and the subsequent risks involved. For these reasons, furnace processes are not recommended for further consideration.

Solvent Extraction Processes

The Israel Chemicals Process: The Penzoil Process

The by-product from the Israel Chemicals Process is a dilute impure aqueous hydrochloric acid containing (in relation to its HCl content) a significant proportion of sulphuric acid and some pentanol solvent. At Mishor Rotem this impure mixed dilute acid stream is fed into an existing phosphoric acid plant using the Israel Chemicals process for the hydrochloric acid attack on phosphate rock, supplementing a constant supply of by-product hydrochloric acid from an adjacent magnesium oxide (periclase) plant, which plant utilises the brines from the Dead Sea and produces hydrochloric acid as the by-product. The hydrochloric acid output of the potassium sulphate process on its own would be neither large enough nor concentrated enough to warrant the construction of such a phosphoric acid plant, even assuming that there would be a ready local market for the phosphoric acid. The only other option would be to neutralize the by-product dilute mixed acid and dispose of the resultant calcium chloride brine. In addition, the solvent consumption of this process would appear to be a further factor in its disfavour.

In the case of the Pennzoil process, as the hydrogen chloride is evolved as a vapour in the bisulphate stage, this process does not suffer from the by-product acid dilution and impurity problems which are the main handicaps of the Israel Chemicals process. The further conversion of the potassium bisulphate intermediate however appears to have existed only on paper to date and is elaborate, with two solvent circuits and a consequent need for fractional distillation. As butyl alcohols and water are miscible to an appreciable extent, and although solvent losses in the aqueous raffinate from the primary extraction are recovered, it is a reasonable supposition that high losses are likely in the dilute sulphuric acid by-product stream unless azeotropic distillation is employed. This would add significantly both to operating and investment costs. Again, the by-product acid in this process is of too low a concentration to be of any commercial value without concentration and would have to be neutralized and disposed of, again adding to the overall costs.

Processes Using Other Sulphates

Magnesium sulphate based processes: The Kali und Salz Process:

The Kali und Salz process came into being mainly because kieserite is produced from the same mine as the potassium chloride ores. There is no known source of magnesium sulphate in the Province and this process would not be appropriate for a location remote from any such source of magnesium sulphate.

The PCS Glaserite process is based on sodium sulphate and is inherently incapable of operation on any substitute. There are a number of questions still outstanding regarding the viability of the process, the possible need to use purified sodium sulphate rather than crude product as a raw material and the operating costs and recovery characteristics. There is no known source of sodium sulphate within the Province and as the prospective source of sodium sulphate weighs heavily in any consideration of this process, it is recommended that this alternative be dismissed from further consideration.

The Atlantic Analytical Process (Pritchard Fraxon)

An independent investigation of this process indicated that the basic chemical reactions claimed did indeed take place. However, satisfactory yields of the required intermediate were only formed $0^{o}C$. A reaction time of some 24 hours per batch would result in additional reagent and plant requirements, especially considering the low temperatures necessary for the reaction.

A further drawback of the process is the volume of acetone required. Tests indicate that four times the volume of acetone will be required over the volume of potassium chloride solution. Acetone is both volatile and inflammable so special precautions would be required to guard against solvent losses and fire hazards while large equipment would be required to handle the necessary volumes. Finally the process route suggested produces the sulphite not the sulphate. Conversion of potassium sulphite to sulphate requires an energy input comparable to that of the Mannheim process. If such elevated temperatures are required to produce the sulphate from the sulphite then the process route reference must obviously lie with a furnace process already well established e.g. the Mannheim or the Chisso. For these reasons it is recommended that this process does not warrant further consideration at this time.

Processes Recommended for Further Study

Calcium Sulphate as the Primary Sulphur Source

The IMI Process

As noted on page 48 "This process would be of prime interest in a location near a natural gypsum mine or a wet-process phosphoric acid plant". The process is presently being developed in Israel utilizing the waste phosphogypsum from phosphoric acid production as a sulphur source having regard to the fact that Israel is totally dependent on imported sulphur for its needs, having no indigenous supply either of elemental sulphur or of pyrites. Although the common contaminents of phosphogypsum such as phosphates, fluoride and silica do not appear to have any marked effect on the reaction they remain in the final product so that the purity of the potassium sulphate is a direct function of the purity of the phosphogypsum used. Israel Chemicals will use phosphogypsum waste product as their raw material.

In New Brunswick however the situation is different. A previously worked deposit of high-grade gypsum is located in the Hillsborough-Albert Mines area of Albert County. This district has been the centre of an active gypsum industry for over 100 years. Production was carried out by the Albert Manufacturing Company until 1930, and then by the Canadian Gypsum Company Ltd until the early 1980s when the operation was shut down. The grade of gypsum at the mine location would appear to be most suitable as a raw material source for the IMI process. Its location, within easy distance of the Sussex potash deposits and the availability of rail and road links would seem to make it a logical source of required raw material for this process. Reserves would appear to be adequate for long term exploitation.

The techniques employed in the process are well known. For example, the technology for handling the ammonia input is well established, as it has long been used in the Solvay process for the production of sodium carbonate. Preliminary estimates suggest that for a 150,000 tonnes product per annum plant under conditions prevailing in Israel (and having to use impure phosphogypsum as the feedstock) the capital cost of such a plant would be less than 50% of a correspondingly sized Mannheim plant and the energy consumption would be some 30% lower.

The Prodeco Process

This process appears to have been successfully demonstrated under laboratory conditions. Although initial work on this process was carried out using sodium sulphate the process is not limited to using it. Ammonium sulphate has been specified as an alternative in which case ammonia would leave the process as ammonium chloride brine. This could be treated with lime to recover ammonia which could be re-absorbed in sulphuric acid to generate ammonium sulphate.

The primary sulphate source would thus be sulphuric acid and the by-product would be calcium chloride, not hydrochloric acid. Ammonia would be required in sufficient quantity for make up and gypsum (from the Hillsborough deposit) could be used to compensate for calcium losses in the process.

From the laboratory work so far conducted the process appears to offer an elegant route from sulphuric acid and potassium chloride to potassium sulphate which does not involve the generation and the requirement to handle and to dispose of hydrogen chloride gas or hydrochloric acid solutions. Raw material potash and gypsum are available locally and sulphuric acid ammonia and lime are freely available from adjacent Provinces.

RECOMMENDATIONS

1. Discussions should take place with Israel Chemicals Ltd with respect to obtaining further information on the IMI (TAMI) Institute for Research and Development Ltd) process using gypsum. Discussions should center on (i) the use of the process under licence (ii) a joint venture operations between Israel Chemicals (or one of its EEC Subsidiaries such as Amfert or Guilini in West Germany) directed to the construction of a potassium sulphate plant in New Brunswick utilizing the high grade gypsum deposit at Hillsborough and/or (iii) additional development work as required to completely prove the process.

2. The necessary secrecy agreements to be exchanged with the patent owners of the Prodeco Process to allow a complete evaluation of the process and the claims thereof. In order to establish the operating capability and the reliability of this process (presently examined only in the laboratory) further laboratory investigation should be undertaken by an independent research laboratory to determine the operating parameters and to prove the process.

3. Additional field work should be carried out directed to the determination of offshore markets for potassium sulphate from a St. John storage location, where the logistics of ocean freight, coupled with the low cost of domestic transportation from the new plant to the port of St. John will show considerable net back advantages over product produced at the Potash Corporation of Saskatchewan's probable plant at Cory or Lanigan, Saskatchewan.

ADDENDUM

Recently Superphos have disclosed that they are considering production of potassium sulphate using a process with gypsum as the sulphur source. No details are presently available, but the Consultants consider that this process should be discussed and examined in conjunction with the Israel Chemicals Ltd process recommended, as both are based on gypsum technology.

PART II

The Market for Potassium Sulphate in Canada

During the week commencing 13 May field visits were carried out in Canada amongst fertilizer producers and users to establish the current status and the future potential market for potassium sulphate (SP) in Canada.

Fieldwork was concentrated on the provinces of Ontario and Quebec as the vast majority of the SP used in Canada is consumed in these two provinces.

Statistical Background

Two of the main problems in assessing the market for SP in Canada and the USA are the shortage of and the inadequacy of the statistical data on SP.

Since 1970 the Potash and Phosphate Institute (PPI) of North America have published statistics on sales of SP and potassium magnesium sulphate (SPM) by province for Canada and by state for the USA.

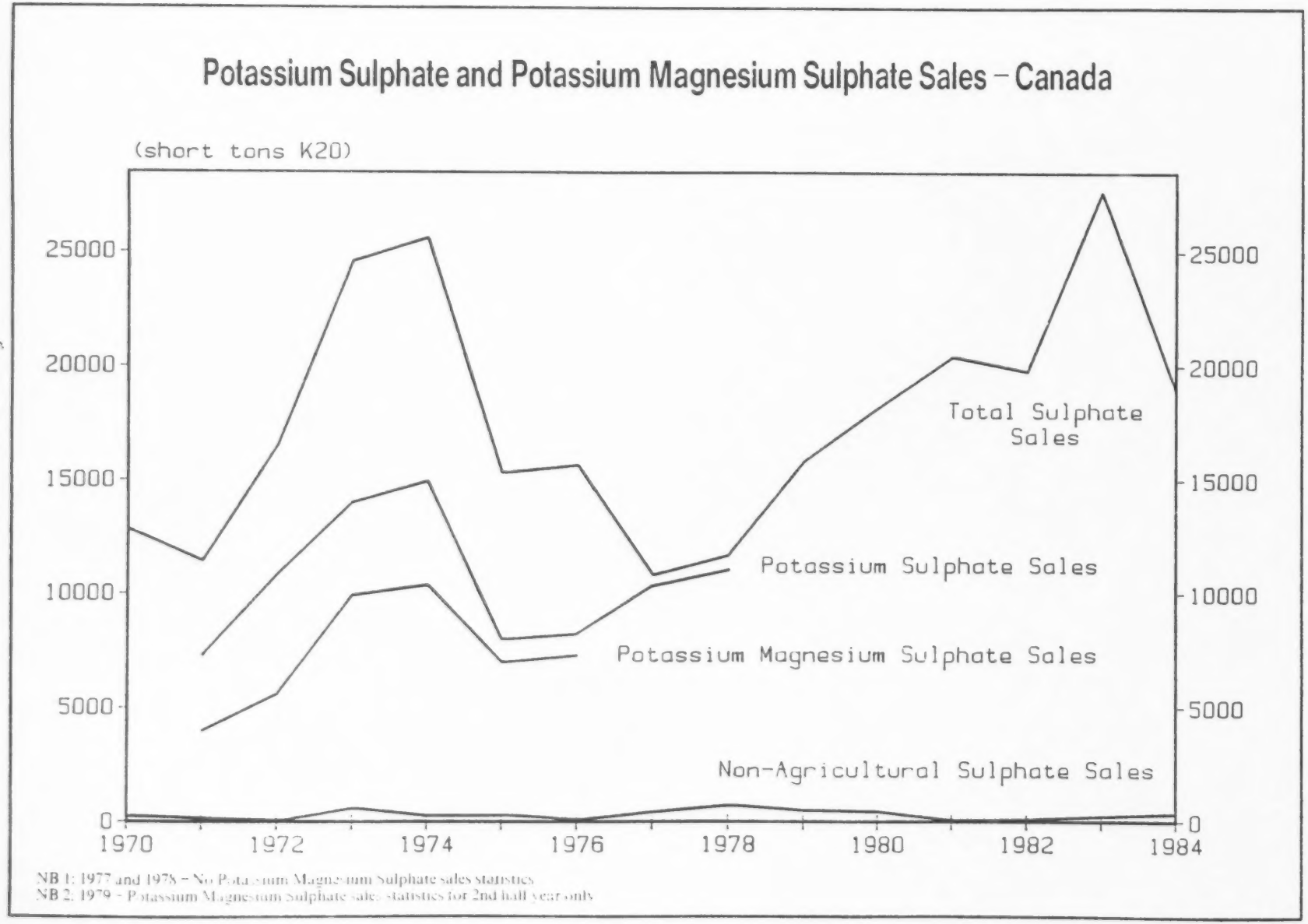
Up to 1976 separate statistics on SP and SPM as well as statistics on potassium sulphates (not differentiated) for non-agricultural use were available. In 1977 and 1978 however only SP statistics were given whilst in 1979 the statistics only include SPM for the second half of the year. Since 1980 only a total figure for SP and SPM under the heading "sulphates" has been given.

The statistical information for the period 1970 - 1984 has been graphed (see Graph 1) whilst the actual figures for the period 1976 - 1979 incl. are given in Table 1 and the combined statistics for the period 1980 - 1984 are given in Table 2.

As Tables 1 and 2 show, sales of SP and SPM are concentrated in the provinces of Ontario and Quebec. Over the five year period 1980 - 1984 incl. average annual sales of "sulphates" in Canada were 21,007 short tons K_2O of which Ontario accounted for an average of 11,864 short tons K_2O and Quebec 6,938 short tons K_2O, a combined average of 18,802 short tons K_2O or 89.5% of the annual average for Canada.

The Maritime provinces of New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland accounted for 1,289 short tons K_2O of sulphates in 1984 or 6.3% of the total, whilst small quantities are also used in British Columbia and the Prairie Provinces.

Statistics showing separate SP and SPM consumption in the provinces of Ontario and Quebec have been obtained from the Canadian Fertilizer Institute (CFI) but statistics for the other provinces are not available, but as mentioned previously as the vast majority of the "sulphates" used are in Ontario and Quebec this is probably not too serious a problem. The consumption figures obtained from the CFI are also believed to be under-representative of the quantities of SP and SPM used in each province due to non-reporting or under-



NB 1: 1977 and 1978 – No Potassium Magnesium Sulphate sales statistics
NB 2: 1979 – Potassium Magnesium Sulphate sales statistics for 2nd half year only

Table 1

Potassium Sulphate and Potassium Magnesium Sulphate Sales - Canada
(short tons K_2O)

PROVINCE	1976			TOTAL	1977			TOTAL
	Agri K_2SO_4	Agri KMg SO_4	Non-Agricultural Sulphates*		Agri K_2SO_4	Agri KMg SO_4	Non-Agricultural Sulphates*	
Alberta	25	45	26	96	87	n.a.	93	180
British Columbia	242	212	-	454	225	n.a.	93	318
Manitoba	25	80	83	188	25	n.a.	130	155
New Brunswick	50	571	-	621	50	n.a.	-	50
Newfoundland	-	-	-	-	-	n.a.	-	-
Nova Scotia	38	25	-	63	39	n.a.	-	39
Ontario	5,828	3,165	-	8,993	7,903	n.a.	92	7,995
Prince Edward Island	314	476	-	790	324	n.a.	-	324
Ouebec	1,730	2,737	-	4,467	1,742	n.a.	21	1,763
Saskatchewan	-	1	-	1	-	n.a.	26	26
Total	8,252	7,312	109	15,673	10,395	n.a.	455	10,850

*Not differentiated between K_2SO_4 and KMg SO_4

n.a. = statistics not available

Potassium Sulphate and Potassium Magnesium Sulphate Sales Canada
(short tone K_2O)

PROVINCE	1978			TOTAL	1979		TOTAL
	Agri K_2SO_4	Agri KMg SO_4	Non-Agricultural Sulphates*		Agricultural Sulphates**	Non-Agricultural Sulphates*	
Alberta	-	n.a.	211	211	39	136	175
British Columbia	185	n.a.	255	440	290	244	534
Manitoba	-	n.a.	83	83	-	95	95
New Brunswick	49	n.a.	-	49	140	-	140
Newfoundland	-	n.a.	-	-	-	-	-
Nova Scotia	39	n.a.	-	39	114	-	114
Ontario	8,982	n.a.	42	9,024	10,785	-	10,785
Prince Edward Island	440	n.a.	-	440	611	-	611
Quebec	1,403	n.a.	120	1,403	3,391	-	3,391
Saskatchewan	-	n.a.	39	39	-	26	26
Total	11,098	n.a.	750	11,728	15,370	501	15,871

**Potassium sulphate plus potassium magnesium sulphate for second half of year

TABLE 2

POTASSIUM SULPHATE AND POTASSIUM MAGNESIUM SULPHATE: SALES - CANADA
(short tons K_2O)

PROVINCE	1980 Agri	1980 Non-Agri	TOTAL	1981 Agri	1981 Non-Agri	TOTAL	1982 Agri	1982 Non-Agri	TOTAL	1983 Agri	1983 Non-Agri	TOTAL	1984 Agri	1984 Non-Agri	TOTAL
Alberta	241	154	395	217	26	243	161	38	199	123	89	212	107	63	170
British Columbia	450	157	607	831	26	857	667	12	679	718	47	765	633	83	716
Manitoba	56	47	103	158	12	170	93	36	129	143	36	179	22	65	87
New Brunswick	111	-	111	30	-	30	634	-	634	541	-	541	360	-	360
Newfoundland	-	-	-	-	-	-	-	-	-	-	-	-	110	-	110
Nova Scotia	110	-	110	-	-	-	13	-	13	90	-	90	-	-	-
Ontario	12,369	-	12,369	12,408	-	12,408	11,684	-	11,684	14,320	26	14,346	7,383	129	8,012
Prince Edward Island	438	-	438	325	-	325	448	-	448	1,217	-	1,217	819	-	819
Quebec	3,490	-	3,490	6,385	-	6,385	5,952	-	5,952	10,232	-	10,232	8,630	-	8,630
Saskatechwan	-	90	90	11	-	11	-	44	44	-	72	72	-	53	53
TOTAL	17,765	448	18,213	20,365	64	20,429	19,652	130	19,782	27,384	270	27,654	18,564	393	18,957

Agri = Agricultural.
Non-Agri = Non-Agricultural.

1984 TOTAL SALES

Quebec	8,630
Ontario	8,012
Prince Edward Island	819
British Columbia	716
New Brunswick	360
Alberta	170
Newfoundland	110
Manitoba	87
Saskatchewan	53
Nova Scotia	-

reporting by some of the fertilizer producers. The figures given in the table below are consumption figures for the products in bulk blends for subsequent sale to farmers.

SULPHATE OF POTASH AND SULPHATE OF POTASH MAGNESIA CONSUMPTION

ONTARIO AND QUEBEC
YEAR ENDED 30 JUNE
(Metric Tonnes)

	Quebec		Ontario	
	Sulphate of Potash	SPM	Sulphate of Potash	SPM
1984	1,449	25,295	8,726	13,624
1983	1,734	25,540	11,676	15,027
1982	1,932	32,466	11,587	18,587

Source: Canadian Fertilizer Institute.

Ontario

Potassium sulphate consumption in Ontario is concentrated on the tobacco crop. Tobacco is grown in south-west Ontario in two main areas. The largest area is around London, particularly in the counties of Norfolk, Elgin, Brant and Oxford. A secondary area of tobacco growing lies to the east of Toronto in the counties of Durham and Northumberland.

The use of SP is closely linked to provincial government regulations related to the amount of chlorine that is desirable in tobacco.

Quoting from "Tobacco Production Recommendations" 1985 season edition published by the Ontario Ministry of Agriculture and Food.

> **"CHLORINE"** - The level of chlorine must be controlled within narrow limits because of its effect on seedling growth and burn and moisture holding capacity of the cured leaf. A high level of chlorine in the cured leaf lowers the burning quality and causes excess moisture uptake by the leaf. Excess chlorine in the seedbed may be toxic to young seedlings and may also contribute to damage from soluble sales.
>
> **Seedbed** - It is recommended that the special tobacco seedbed fertilizer, 4-30-8 contain no more than 1.25% chlorine.

Flue-cured - The amount of chlorine is regulated as follows: (a) a fertilizer containing less than 2% nitrogen should have a maximum chlorine content of 3% and a minimum of 0; or, (b) a fertizlier containing 2% or more nitrogen shall have a minimum chlorine content equal to the guaranteed nitrogen content and the maximum chlorine shall not exceed the minimum by more than one percent. For example, a 3-9-18 analysis should contain a minimum of 3% and a maximum of 4% chlorine.

Burley - No more than 1.25% chlorine is allowed in the fertilizer".

The regulations relating to flue-cured tobacco are the most significant as regards use of SP because flue-cured tobacco is the most important and also because the regulations are strictly enforced.

Because of the narrow range of chlorine allowed in the fertilizer a high proportion of the potash must be supplied as non-chloride containing potash; hence the need for SP. But the regulations also specify a minimum level of chlorine which necessitates the use of a certain amount of potassium chloride in the fertilizer.

There are also recommendations with regard to the level of water soluble magnesium which are also produced below from "Tobacco Production Recommendations".

"MAGNESIUM

Seedbed - The special tobacco seedbed fertilizer, 4-30-8, should contain a minimum of 2% water soluble magnesium.

Flue-cured - Flue-cured tobacco fertilizers, except for the seedbed fertilizer, should contain a level of water soluble magnesium that is equivalent to 40% of the guaranteed nitrogen content of the fertilizer. For example, a 3-9-18 analysis should contain 1.2% water soluble magnesium.

Burley - Burley tobacco fertilizers should contain 0.6% water soluble magnesium (Mg)".

The above standards for magnesium are recommendations only however, unlike the chlorine standards which are regulations.

The setting of the above standards for magnesium has resulted in the extensive use of SPM in tobacco fertilizer.

Finally it is also worth mentioning the standards recommended for the form of nitrogen as this could have some effect on the quantity of other fertilizers used.

"**NITROGEN** - At least one-quarter of the total nitrogen should be in the nitrate form except for side-dressing fertilizer, in which at least one-half of the nitrogen should be in the nitrate form".

The Ontario Soil Management Research Committee recommends the following analyses for tobacco fertilizers.

FLUE-CURED

Planting and Early Side-dressing Fertilizers

3-6-18
3-9-18 or 4-12-24
3-12-18
2-10-16 or 3-15-24
5-10-30

Late Side-dressing Fertilizers

3-6-18
9-0-27

Seedbed Fertilizer

4-30-8

BURLEY

Field Fertilizers

3-18-18
5-10-15 or 7-14-21

Seedbed Fertilizer

4-30-8

As a result of these standards and regulations the typical tobacco fertilizer contains ammonium nitrate, diammonium phosphate (or granular triple superphosphate or monoammonium phosphate), potassium chloride, granular potassium sulphate and granular potassium magnesium sulphate in various proportions. All tobacco fertilizers are physically blended from the above products rather than chemically compounded, with the average SP content estimated to be around 22% by weight.

It is estimated that between 80% and 95% of the potassium sulphate consumed in Ontario is used on the tobacco crop. Definitive figures are not available however.

The main type of tobacco grown in Ontario is flue-cured tobacco although there are other varieties i.e. burley, light air-cured, dark air-cured and dark fire-cured. In 1984 tobacco production in Ontario totalled 78,555 tonnes of which 77,052 tonnes was flue-cured tobacco. Flue-cured tobacco is also grown in Quebec, PEI, Nova Scotia and New Brunswick but total production in these four provinces in 1984 was only 12,290 tonnes.

The Ontario Flue-Cured Tobacco Growers Marketing Board markets the vast majority of the tobacco produced in Canada and is responsible for regulating production in Ontario to meet probable sales. As the attached table shows statistics produced by the Marketing Board give "target" production figures by

year since 1965. The maximum target figures were reached in 1973 and 1974 when the figure was set at 250 million pounds. Since 1974 the annual target figure has fluctuated up and down but has never exceeded this figure. In the last three years there has been a considerable decline in the "target" figure.

i.e.	1982	238 million pounds
	1983	215 million pounds
	1984	170 million pounds
	1985	170 million pounds (provisional)

The 1984 target figure was the lowest since target figures were first set in 1965 but despite this low figure the minimum prices guaranteed by the Canadian Tobacco Manufacturers Council (CTMC) were unacceptable to Ontario tobacco growers.

In line with the decline in target production has been a corresponding decline in the acreage planted in flue-cured tobacco. Statistics on the acreage planted have not been collected since 1975; but the acreage planted would broadly relate to the "target" production figure. Thus as the target production figure has declined the acreage planted has declined as there has been little change in pounds produced per acre since the early 1970s. A study carried out in 1981 indicated that the yield was around 2,155 pounds/acre, indicating that the area planted in 1981 was around 102,000 acres. Assuming the same yield per acre on the 1984 and 1985 target production figures indicates an area of around 78,000 acres.

Many of the farmers with a small acreage of land for tobacco growing have ceased to plant tobacco as the amount of tobacco they could produce under the target system has declined to levels, at which it was uneconomic to produce any tobacco. Farmers must have "tobacco rights" granted by the Marketing Board in order to grow tobacco, but for several years no new "tobacco rights" have been granted. The situation with regard to burley tobacco is even more serious. Burley production declined from around 7 million pounds in the early 1970s to 3.1 million pounds in 1983 to 1.5 million pounds in 1984. In 1985 however no burley tobacco will be grown in Ontario as the tobacco manufacturers could not guarantee the farmers a minimum price at which they would purchase the crop. The fertilizer recommendations for burley tobacco stress the need to avoid using formulations containing potassium chloride because of the high chlorine level in the product which lowers the burning quality of the leaf. It is also stressed in"Tobacco Production Regulations" that "production of burley with good burning quality is of the utmost importance if the domestic and export markets are to be maintained and expanded". The permanent loss of the burley tobacco crop in Ontario would represent a loss of a small but important market for SP as it is believed that the vast majority of the potash used on burley tobacco was SP.

One of the few other encouraging comments to be made concerning potash application on tobacco came from the Delhi Research Station. It was

mentioned that there was some indication that the potash content of soils in the tobacco growing area was declining slightly. The decline was not severe but it was considered possible that if the trend continued it may be necessary to change the tobacco fertilizer recommendation from the normal 3-6-18 or 3-9-18 to a 3-6-20 or even a 3-9-22.

In addition to tobacco however SP is used in Ontario on many other crops.

Potatoes

After tobacco potatoes is possibly the next largest user of SP although SP faces strong competition from SPM due to the Magnesium requirement of potatoes. Estimates of the quantity of SP used on potatoes in Ontario range from around 20% of the total used to only 1%-2%. In the area around Bradford and Alliston potatoes are grown for processing into French fries and chips. If the farmer is paid on the amount of dry matter in the potato it is quite likely that he will use part or all of his potash in the form of SP. If he is not paid on the amount of dry matter present the quantity of SP used is likely to be less.

Like tobacco farmers potato growers tend to fertilizer their crop well and also like tobacco farmers some may use more fertilizer than is strictly necessary. The potato market is however very volatile, with the acreage planted fluctuating as much as 20% up or down from one year to the next. Several of the fertilizer producers contacted however expressed the view the SPM was agronomically superior to SP for use on potatoes due to its magnesium content. It was also pointed out that there is evidence that SP produces a darker coloured potato than KCl and that this may deter some farmers from using SP.

Other Crops

In addition to tobacco and potatoes SP is also used on a wide range of other crops but the tonnages involved appear to be relatively small. Vegetables and fruit growers use SP and some is also used on lawns and gardens. Estimates of the quantities involved are small, put by one source at only 1%-2% of the total market in Ontario i.e. around 90 to 180 tonnes product. One crop that formerly consumed SP was vines but following the publication of research findings some years ago by Dr. Klein which showed that SP was not necessary on vines, SP use is now minimal on this crop.

One of the contacts interviewed was however quite optimistic about the prospects for growth of SP usage on vegetables, particularly tomatoes, beans, lettuce and cabbage. It was suggested that many of the more progressive farmers, concerned to maximise plant yields were becoming increasingly aware of the benefits of fertilizing with SP. There has been a growth in the use of drip irrigation in the greenhouse industry for which a totally soluble SP is required. It was suggested by one respondent that there were considerable opportunities to expand SP use on vegetables and fruits by more active

marketing and promotion at the local level. Other respondents took a less optimistic view of the potential for use of SP in this market sector.

Quebec

As in Ontario the vast majority of the SP used in Quebec is on the tobacco crop (estimated around 90%) but as the tobacco acreage in Quebec is much smaller total consumption of SP is correspondingly smaller.

Total tobacco acreage in Quebec is around 10,000 acres at present compared with around 80,000 acres in Ontario and total consumption of SP was put by the CFI at 1,449 tonnes in 1983/84 compared with 8,726 tonnes for Ontario.

As in Ontario the vast majority of the tobacco grown in Quebec is flue-cured but in addition some cigar-filler and pipe tobacco is also grown. Statistics for 1983 and 1984 are given below:

Quebec Tobacco Production

	1983	1984
	Kg	
Flue-cured	7,201,722	7,222,734
Cigar filler	425,000	475,000
Pipe	25,000	25,000
Total	**7,651,722**	**7,722,734**

There were 134 flue-cured tobacco producers in Quebec in 1984 compared with 2,509 producers in Ontario, indicating that the average production per producer is much greater in Quebec than in Ontario.

In the mid-1960s flue-cured tobacco production in Quebec totalled around 6,000 pounds pa, but unlike Ontario where production has declined since the mid-1960s production in Quebec has increased, totalling 14 million pounds in 1982 and 15.9 milion pounds in 1983 and 1984. The reason for this increase is that the Canadian Tobacco Manufacturers Council (CTMC) has been prepared to buy as much tobacco as the producers are able to produce up to a certain limit. The same consideration appears to apply to the other tobacco producing provinces of PEI, Nova Scotia and New Brunswick. Political influences appear to be behind this purchasing policy. In 1984 however for the first time the CTMC placed a limit on the amount of tobacco they would purchase from the Quebec tobacco growers.

If it is assumed that SP consumption in Quebec is around 2,000 tonnes and that 90% of the SP is used on tobacco, usage on other crops is very limited at around

ONTARIO FLUE-CURED LEAF TOBACCO PRODUCTION AND MARKET ANALYSIS

(for years 1957 to 1983 inclusive)

Crop Year	% Cut	Acreage Planted	Poundage Target	Poundage Sold by Auction	Poundage Packed and Stored	Pounds Produced per Acre	Dollar Return Per Acre	Average Price Paid Per Lb ¢	Anticipated Price Paid Per Lb ¢	Method of Marketing	Crop Year
1957	-	117,885	-	147,687,219	-	1,252	$ 643	50.32 (plus)	49.00	Arbitrated crop prices	1957
1958	15.0	117,672	-	173,213,818	1,635,867	1,504	706	47.57	-	Arbitrated grade prices	1958
1959	25.0	111,224	-	145,227,434	11,407	1,307	733	57.62	53.96	Arbitrated grade prices	1959
1960	15.0	123,816	-	198,898,722	16,932	885	885	56.61	54.59	Arbitrated grade prices	1960
1961	20.0	122,287	-	182,962,258	7,176,000 +	1,560	784	55.37	52.17	With Gov't Assistance	1961
1962	25.0	116,571	-	156,235,682	23,846,746 +	1,545	789	55.26	53.34	With Gov't Assistance	1962
1963	40.0	99,535	-	179,006,424	746,000	1,802	843	46.84	-	Deficiency Price	1963
1964	55.0	73,535	-	136,454,800	nil	1,857	1,052	56.66	-	Open Auction	1964
1965	45.0	86,870	170,000,000	153,981,705	nil	1,773	1,169	65.96	50.00	Memorandum	1965
1966	17.5	117,548	228,000,000	214,702,824	29,090	1,827	1,303	71.36	60.00	memorandum	1966
1967	9.8	128,129	238,275,000	195,894,131	440,736	1,529	1,056	69.08	66.00	Memorandum	1967
1968	18.5	122,083	205,000,000	200,417,192	171,082	1,642	1,170	71.28	67.00	Memorandum	1968
1969	23.0	117,658	200,000,000	226,312,476	11,294	1,923	1,276	66.36	67.00	Memorandum	1969
1970	42.3	92,289	172,500,000	199,013,529	22,519	2,158	1,406	65.16	68.00	Memorandum	1970
1971	50.0	81,270	176,900,000	201,779,346	nil	2,483	1,614	65.00	69.00	Memorandum	1971
1972	46.0	86,701	200,000,000	166,741,622	23,893	1,925	1,500	77.99	70.00	Agreement with CTMC	1972
1973	33.0	104,679	250,000,000	232,790,623	21,888	2,224	1,766	79.40	72.50	Agreement with CTMC	1973
1974	28.6	108,761	250,000,000	238,063,591	51,299	2,189	1,974	90.17	83.00	Agreement with CTMC	1974
1975	42.0	87,702	202,000,000	209,581,694	5,674	2,390	2,390	94.02	94.00	Agreement with CTMC	1975
*1976	54.5	-	175,000,000	159,048,586	4,982	-	-	102.09 **	100.00	Agreement with CTMC	1976
1977	50.5	-	205,000,000	204,848,908	-	-	-	109.44 **	100.00	Agreement with CTMC	1977
1978	40.1	-	230,000,000	229,587,111	-	-	-	118.44 **	106.50	Agreement with CTMC	1978
1979	40.1	-	230,000,000	149,229,274	-	-	-	132.93 **	116.00	Agreement with CTMC	1979
1980	41.2	-	226,000,000	213,695,523	-	-	-	136.47 **	128.00	Agreement with CTMC	1980
1981	42.7	-	220,000,000	219,887,246	-	-	-	151.93 **	142.00	Agreement with CTMC	1981
1982	38.1	-	238,000,000	153,568,923	-	-	-	161.79 **	156.00	Agreement with CTMC	1982
1983	44.0	-	215,000,000	214,872,728	-	-	-	163.37 **	160.00	Agreement with CTMC	1983

\+ Processed by the local board (For crop years other than 1961 and 1962 growers had tobacco redried and packed for thie own account)

* First crop grown under poundage control

** Guaranteed portion of the crop averaged 103.83 ¢ in 1976, 110.40 ¢ in 1977, 119.29 ¢ in 1978, 134.78 ¢ in 1979, 137.41 ¢ in 1980, 152.13 ¢ in 1981, 162.86 ¢ in 1982 and 163.84 ¢ in 1983.

Source: "The Ontario Flue-Cured Tobacco Growers Marketing Board Annual Report 1984"

200 tonnes. Nutrite commented that they knew of nobody using SP on potatoes or other vegetables in Quebec. Some SP is probably used on fruits such as strawberries and raspberries.

As the statistics indicate, a much greater quantity of SPM than SP is used in Quebec. In addition to tobacco SPM is used on apples, corn, potatoes and other vegetables in magnesium deficient areas. Heavy promotional activity by IMC is thought to be behind the relatively high use of SPM in Quebec.

The Suppliers

As at present there is no SP production in Canada (despite several attempts by companies in Ontario, Saskatchewan and British Columbia) all the SP used in Canada therefore has to be imported.

The main suppliers, following discussions with the importers, appear to be International Mineals and Chemical Corporation (IMC), Great Salt Lake Minerals and Chemicals Corporation (G.S.L.) and Potash Company of America (P.C.A.) in the United States. Some SP has also been imported recently from overseas via the USA.

The biggest suppliers are believed to be IMC and G.S.L. with around 90% of the market in Ontario. IMC also supplies SPM which it promotes extensively and possibly at the expense of SP, which is more costly to produce and which is therefore a less attractive product for a producer concerned to mimise costs of production. The other major supplier, G.S.L. will be out of production probably until at least 1988 following the flooding of its brine collection ponds in 1984. G.S.L. has been shipping product out from stock until recently but inventories are now understood to be exhausted.

The other supplier of SPM is Duval although it would appear that IMC is probably the main supplier as most importers refer to SPM by the IMC brand name Sul-Po-Mag rather than K.Mag which is the Duval brand name for SPM.

Potassium sulphates from the USA is either railed from New Mexico to Houston, TX and then conveyed bu bulk carrier across the Gulf of Mexico up the east coast of the USA down the St. Lawrence River to Hamilton or railed all the way across the United States and then shipped across Lake Erie to Port Stanley. It is estimated that around 25% of sulphates are transported by water and 75% by rail. The cost of freight from New Mexico to Quebec is Can$83 per tonne.

The Importers

The main importers/users of SP and SPM in Canada are as follows:

Ontario

United Co-operative of Ontario (U.C.O.)
C.I.L. Inc.
Cyanamid Canada Inc.
Nutrite Inc.

U.C.O. estimate that they have around 30% of the Ontario market for fertilizers and about 20% of the market for tobacco fertilizers. They put their annual consumption of SP at about 2,000 tonnes.

In Ontario C.I.L. are estimated by U.C.O. to use about the same quantity of SP as U.C.O. i.e. around 2,000tonnes, but taking the whole of Eastern Canada as one region i.e. Ontario, Quebec and the Maritimes C.I.L. estimate they probably use more SP than any other fertilizer producer. C.I.L. buys its SP from IMC.

Cyanamid Canada Inc. also buy around 2,000 tonnes SP each year. They were one of the few organizations to be relatively optimistic about the future of SP sales in Canada particularly for high income vegetable crops.

Nutrite use around 1,200 tonnes SP in Ontario.

Other SP users in Ontario include Agrico who use around 100-200 tonnes SP p.a., and some of the independent companies such as Misner Fertilizers Ltd., Norwich Fertilizers Ltd. Bradford Fertilizers (60 t/a) Burford Fertilizers and Norfolk Co-operative Ltd.

Quebec

Although statistics from the Canadian Fertilizer Institute put SP consumption in Quebec at 1,449 tonnes for fertilizer year 1983/84 consumption is believed to be higher than this with estimates by the producers in the range 2,000 tonnes - 2,500 tonnes.

One of the largest users is Fertico who provided the following estimates of annual consumption.

Fertico	700 tonnes
C.I.L.	700 tonnes
Cyanamid Canada	500 tonnes
Co-op Federee	300 tonnes
Nutrite	200 tonnes
William Houde Ltd.	100 tonnes

Fertico produce around 11,000 tonnes of speciality fertilizers p.a. for the tobacco growers, greenhouse farmers and for lawns and gardens. Fertico are located in the Quebec tobacco growing region around Joliette and L'Asumption.

Outlook

The prospects for increased use of potassium sulphate on tobacco in Canada are not good. The acreage planted to tobacco in Ontario is tending to decrease as demand for tobacco in Canada declines and as the export potential for Canadian tobacco decreases in the face of strong competition from other exporting nations.

The main problem of the tobacco industry in Ontario as stated in the 1984 Annual Report of the Marketing Board is "the present system of taxation on tobacco products being used by the federal and provincial governments".

In 1984 the Liberal Federal Government accepted a recommendation from a Marketing Board Task Force that the annual indexation of excise duty and tax on cigarettes be directly related to the overall rate of inflation, but since the election of the Conservative Government this policy has been scrapped. In the Federal Government budget handed down on 23rd May the Federal tax on cigarettes was increased by 1 cent/cigarette. Furthermore the Quebec provincial government has also recently imposed an additional 20 cents per packet increase on a packet of 20 cigarettes. In Quebec therefore combined Federal and provincial taxes on a packet of 20 cigarettes now total Can$1.36 compared with 96 cents before the recent increases, a 41.6% increase. Any increases in the level of provincial taxes in the other provinces has not been announced yet but as Quebec consumes around 38% of the tobacco used in Canada the aguries for the Canadian tobacco industry following this latest round of taxation increases are not good.

The Ontario and PEI tobacco growers are co-sponsoring a proposal to create a National Tobacco Marketing Agency with a two-tier pricing system. Discussions on this agency are at an early stage at present but the objectives are to subsidise the export price with a higher domestic price. The Ontario producers have been losing many of their main export markets to cheaper tobacco from Brazil and Zimbabwe and the creation of a National Marketing Agency is an attempt to recover these markets. Up to 40% of the Ontario crop is given for export and the loss of export markets is a severe blow to the industry.

The Ontario Marketing Board believe that they can maintain production at around 170 million pounds p.a. if they are successful in creating this new agency but if they are not, the prospects are for continued decline in the tobacco acreage in Ontario and therefore a continued decline in SP consumption.

There may be continued small increases in the tobacco acreages and SP consumption in Quebec and the other provinces growing tobacco if the CTMC resumes its policy of purchasing more tobacco from these provinces. As far as SP consumption on tobacco is concerned however there would be no net increase in consumption, merely a switch from Ontario to the other provinces.

The use of SP on crops other than tobacco appears to be limited at present, at perhaps a maximum of 1,800 tonnes in Ontario and 200 tonnes in Quebec, or 2,000 tonnes in total. Some respondents foresaw the prospects for a good increase in sales of SP for vegetables whilst others were not so sanguine. On balance it appears from the research carried out, that there will be a steady decline in SP use on tobacco and perhaps an equally steady increase for use on other crops.

The Market for Potassium Sulphate in the Eastern United States

Field visits were carried out in the US states of Florida, Georgia, North Carolina and South Carolina during May 1985 as these states on the East Coast of the USA would be key markets for potassium sulphate shipped out from New Brunswick.

Statistical Background

As described in the section on Canada there are shortcomings in the statistics available on SP sales and consumption in North America. PPI statistics on sales of "sulphates" by state are given in Table 3 whilst in Table 4 both domestic sales and imports of sulphates from overseas are given together with a table listing in descending order of tonnage the sales total for 1984.

In addition sales statistics for the period 1970-84 eastern seaboard states from Maine down to Florida together with the states of Alabama, Louisiana and Mississippi in the Gulf of Mexico have been extracted and graphed in graph 2. Most of these states are good potential markets for New Brunswick potassium sulphate due to their coastal location. Potassium sulphate is imported from overseas by several of these states. A complete list of the 19 states is given in the Appendix.

As the graph indicates the largest sales volume into these 19 states was in 1970 at 155,274 s.tons K_2O with imports comprising 23% of the total. Sales approached this level again in 1980 at 148,742 s.tons K_2O but have since declined to less than 120,000 s.tons K_2O. Particularly noticeable since 1980 has been the drop in domestic sales of agricultural grades sulphates from 124,490 s.tons K_2O in 1980 to around 86,000 s.tons K_2O in 1983 and 1984. Imports from overseas which dropped to only 7,000 s.tons K_2O in 1982 totalled 31,349 s.tons K_2O in 1984 (26% of the total).

TABLE 3

POTASSIUM SULPHATE AND POTASSIUM MAGNESIUM SULPHATE: SALES - USA

(short tons K_2O)

STATE	1980 Agri	1980 Non-Agri	TOTAL	1981 Agri	1981 Non-Agri	TOTAL	1982 Agri	1982 Non-Agri	TOTAL	1983 Agri	1983 Non-Agri	TOTAL	1984 Agri	1984 Non-Agri	TOTAL
Alabama	8,334	-	8,334	5,241	-	5,241	3,280	32	3,312	2,431	-	2,431	3,365	-	3,365
Arizona	1,213	-	1,213	1,148	37	1,185	496	26	522	290	39	329	176	12	188
California	29,948	742	30,690	21,352	617	21,969	19,874	260	29,134	19,308	613	19,921	21,932	781	22,713
Colorado	4,073	26	4,099	2,964	27	2,991	2,322	38	2,360	2,201	39	2,240	2,611	63	2,674
Florida	53,762	-	53,762	40,472	-	40,472	42,013	-	42,013	44,353	-	44,353	38,768	-	38,768
Georgia	27,298	152	27,450	22,425	181	22,606	15,475	156	15,631	14,884	310	15,194	18,825	256	19,081
Hawaii	1,324	-	1,324	975	-	975	1,122	-	1,122	737	-	737	227	-	227
Idaho	4,971	-	4,971	6,361	-	6,361	5,108	-	5,108	6,020	-	6,020	3,272	-	3,272
Illinois	4,173	-	4,173	3,162	-	3,162	2,950	-	2,950	3,434	11	3,445	2,886	26	2,912
Indiana	6,055	-	6,055	5,550	-	5,550	3,294	-	3,294	3,398	12	3,410	2,347	11	2,358
Iowa	1,049	-	1,049	752	-	752	569	-	569	1,156	-	1,156	947	-	947
Kansas	1,306	81	1,387	1,218	80	1,298	1,082	66	1,148	1,466	100	1,566	1,924	66	1,990
Kentucky	28,388	-	28,388	33,799	-	33,799	28,031	-	28,031	26,526	-	26,526	15,165	-	15,165
Maine	1,168	-	1,168	1,152	-	1,152	894	-	894	1,098	3	1,101	505	-	505
Maryland	1,101	168	1,269	2,067	21	2,088	2,361	42	2,403	1,280	63	1,343	1,490	73	1,563
Michagan	1,690	343	2,048	2,055	319	2,374	1,962	373	2,335	2,596	188	2,784	2,728	421	3,149
Minnesota	1,832	-	1,832	2,175	-	2,175	2,142	-	2,142	3,229	-	3,229	3,380	-	3,380
Missouri	1,462	1,006	2,468	1,025	1,224	2,249	1,039	808	1,847	980	732	1,712	935	854	1,789
Nebraska	14,306	-	14,306	11,281	13	11,294	7,940	-	7,940	6,973	-	6,973	7,162	51	7,213
New Mexico	1,377	-	1,377	1,308	-	1,308	1,358	-	1,358	965	-	965	4,358	-	4,358
New York	2,954	-	2,954	2,580	-	2,580	2,435	-	2,435	2,450	-	2,450	2,598	-	2,598
North Carolina	14,345	-	14,345	15,518	-	15,518	10,916	-	10,916	6,732	-	6,732	7,622	-	7,622
Ohio	5,990	-	5,990	6,244	-	6,244	6,191	-	6,191	7,174	-	7,174	5,174	-	5,174
Oklahoma	1,056	105	1,161	831	105	936	655	58	713	995	120	1,115	1,023	113	1,136
Oregon	1,642	-	1,642	1,507	-	1,507	1,209	-	1,209	1,689	-	1,689	2,094	-	2,094
Pennsylvania	1,440	52	1,492	1,869	21	1,890	2,247	-	2,247	2,675	42	2,717	2,657	84	2,741
South Carolina	9,173	11	9,184	9,594	22	9,616	5,709	16	5,725	5,957	32	5,989	6,574	1	6,575
Tennessee	7,501	-	7,501	6,069	-	6,069	8,546	21	8,567	10,665	-	10,665	3,716	13	3,729
Texas	17,839	326	18,165	12,789	294	13,083	13,231	276	13,507	8,408	200	8,608	8,791	189	8,980
Virginia	2,219	-	2,219	2,438	-	2,438	2,525	-	2,525	1,485	11	1,496	1,597	-	1,597
Washington	3,059	39	3,098	2,968	26	2,994	2,682	38	2,720	2,766	25	2,791	3,071	-	3,071
Wisconsin	4,364	-	4,364	4,904	-	4,904	3,361	-	3,361	4,148	-	4,148	3,529	-	3,529
Others*	3,986	2,416	6,402	5,729	1,734	7,463	3,731	862	4,593	4,231	1,110	5,341	4,860	1,120	5,980
TOTAL	270,398	5,467	275,865	239,622	4,721	244,343	206,750	3,072	209,822	202,701	3,650	206,351	186,309	4,134	190,443

* Alaska, Arkansas, Connecticut, Delaware, Louisiana, Massachusetts, Mississippi, Montana, New Hampshire, New Jersey, North Dakota, Rhode Island, South Dakota, Utah, Vermont, West Virginia, Wyoming

Agri = Agricultural.
Non-Agri = Non-Agricultural.

TABLE 4

POTASSIUM SULPHATE AND POTASSIUM MAGNESIUM SULPHATE: TOTAL SALES - USA DOMESTIC AND IMPORT
(tonnes K_2O)

STATE	1980 Domestic	1980 Import	1980 TOTAL	1981 Domestic	1981 Import	1981 TOTAL	1982 Domestic	1982 Import	1982 TOTAL	1983 Domestic	1983 Import	1983 TOTAL	1984 Fert & Ind. Domestic	1984 Import	1984 TOTAL
Florida	53,762	-	53,762	40,572	-	40,572	42,013	-	42,013	44,353	6,340	50,693	38,768	12,786	51,554
Louisiana	1,415	-	1,415	677	-	677	68	-	68	84	2,955	3,039	104	8,666	8,770
Maryland	1,269	524	1,793	2,088	-	2,088	2,403	252	2,655	1,343	1,662	3,005	1,563	101	1,664
North Carolina	14,345	14,898	29,243	15,518	14,304	29,822	10,916	4,234	15,150	6,732	10,391	17,123	7,622	8,781	16,403
Virginia	2,219	7,962	10,181	2,438	-	2,438	2,525	2,416	4,941	1,496	4,281	5,777	1,597	1,015	2,612
TOTAL IMPORT		23,384			14,304			6,902			25,629			31,349	

SALES TOTALS 1984
(short tons K_2O)

Florida	51,554
California	22,713
Georgia	19,081
North Carolina	16,403
Kentucky	15,165
Texas	8,980
Louisiana	8,770
Nebraska	7,213
South Carolina	6,575
Ohio	5,174
New Mexico	4,358
Tennessee	3,729
Wisconsin	3,529
Minnesota	3,380
Alabama	3,365
Idaho	3,272
Michagan	3,149
Washington	3,071
Illinois	2,912
Pensylvania	2,741
Colorado	2,674
Virginia	2,612
New York	2,598
Indiana	2,358
Oregon	2,094
Kansas	1,990
Missouri	1,789
Maryland	1,664
Oklahoma	1,136
Iowa	947
Maine	505
Hawaii	227
Arizona	188

OTHERS 5,980 tons for:

Alaska
Arkansas
Connecticut
Delaware
Massachusetts
Mississippi
Montana
New Hampshire
New Jersey
North Dakota
Rhode Island
South Dakota
Utah
Vermont
West Virginia
Wyoming

Florida and Georgia are the largest buyers of sulphates, although the largest buyer of potassium sulphate was formerly North Carolina. In 1971 domestic SP sales into North Carolina totalled 18,563 s.tons K_2O, with in addition, sales of 3,086 s.tons K_2O as SPM. By 1978 however SP sales had fallen to 9,412 s.tons K_2O and in 1984 total domestic sulphate sales were only 7,622 s.tons K_2O. Furthermore over the same period there has been a decline in imports of SP from overseas from around 15,000 s.tons K_2O in the late 1970s to early 1980s to an average of less than 10,000 s.tons K_2O in the last three years. It is probable that Florida is new the largest user of SP on the east coast. Total sulphate sales are around the same level as in the early 1970s and although there were no imports into the state during the period 1976-198 imports resumed in 1983 and totalled 12,786 s.tons K_2O in 1984.

Analysis of Potassium Sulphate Consumption in the Eastern United States

For the USA, SP consumption has been analysed on a crop basis concentrating as mentioned previously in Florida, Georgia, North Carolina and South Carolina. There is very little SP consumption in the north-east states of New England. The state using the largest volume of sulphates in 1984 was New York with 2,600 s.tons K_2O of which it is estimated only 500 s.tons K_2O was SP.

Tobacco

Consumption of tobacco in the United States began its decline in 1981 and has fallen every year since. Over the years there has been a considerable level of overproduction of tobacco and the estimtes for 1985 acreage suggest a 10% reduction to some 715,000 acres.

US tobacco producers are coming under increased competition from lower priced tobacco from Brazil and from Africa, particularly Zimbabwe. Currently about one third of the tobacco used in US cigarette production is imported product. Flue-cured tobacco acreage has decline to 361,000 acres, a drop of 50%, in just ten years.

The consensus of opinion within all aspects of the industry is that production will continue to decline for at least a further two if not three years more and then may stabilize for a few years. However, the long term outlook is for continuing decline within the industry. Per capita consumption of cigarettes in the United States has dropped about 15% over the last ten years due to a combination of anti-smoking pressures and increased costs and taxes. Currently the market outlook is even more uncertain as negotiations are presently underway between the "Flue Cured Tobacco Stabilization Co-operative", representing some 60,000 individual tobacco growers and the cigarette companies to set up a new tobacco programme for the 1986 season and thereafter. Tobacco is not included in the US agricultural legislation but is left as an industry agreement.

The present system of price support has priced US produced tobacco out of world markets, allowing production to fall to some 50% of what it was in 1975. US cigarette companies are purchasing ever greater percentages of their requirement from overseas, although the quality of the offshore tobacco is generally inferior to home produced product.

The current programme allows the farmer to sell tobacco to the co-operative if the market price is US$1.54 per 100lbs or less. The co-operative borrows money from the Commodity Credit Corporation (a US Government agency) and pays the farmer US$1.74 per 100 lbs. The farmer in turns pays the co-operative 25 cents per 100 lbs for storage and interest costs. As a result of this system there is currently some 800 million pounds of tobacco in storage.

Overseas product still sells for some 85 cents per 100 lbs f.o.b. the offshore country port. Shipping costs are variable but would not appear to exceed 60 cents per 100 lbs.

Current negotiations centre around US companies purchasing the 800 million lbs of tobacco surplus over a five year period and, in return the growers would reduce the support price to be competitive with imported product, say at around $1.40 per 100 lbs. The US government has cleared this proposal from any possible anti-trust problems but already some companies have been threatened with "class action" law suits from growers who do not wish to see the support price lowered. The tobacco companies are now looking at Congressional action to protect them from such law suits before they agree to the overall plan.

An added problem with the present pricing structure is that US producers have traditionally exported some 50% of production as leaf plus a further 10% as finished cigarettes. The US producers are gradually losing these markets to lower priced product particularly from Brazil and from Africa.

If the proposed programme for the lowering of the support goes forward it is still expected that it will take some 3 to 4 years to be completely implemented and to work off the surplus stock. After the "mopping-up" of the present surplus both acreage and poundage allotments could be expected to be increased. Some opinions suggest that the overall market must still be satisfactory and cite the opening of a US$2 billion factory in North Carolina by R.J. Reynolds and Phillips Morris's construction of a further plant. However, critics suggest that this could be a cost cutting exercise related to the construction of high output modern factories, not related to any expected growth in the tobacco market.

Tobacco Fertilization

By law fertilizer used on tobacco can contain only a limited chloride content and as a result only non-chloride products are used on this crop.

Although chloride does not affect growth of the tobacco plant, uptake in the leaf is detrimental to the burning qualities of the tobacco. There is a limit of 2% of total chloride in all fertilizers used on the tobacco crop.

In past years the main fertilizer used was a 3-9-9 product at one ton to the acre, i.e. 180 lbs K_2O per acre. More recently the extension services are recommending the use of 6-6-18 at 800 to 1,000 lbs per acre (i.e. from 144 to 180 lbs of K_2O per acre) with a side dressing of sodium nitrate. Most of the product is continuous ammoniation product, much of which is produced by IMCC using their own "Sul-Po-Mag". However it is reported that, particularly in South Carolina, if the farmer carries out his liming efficiently there will be no magnesium deficiency, which would preclude the requirement to use potassium magnesium sulphate, as liming is the cheapest method of magnesium application.

A further interesting observation is that in some quarters it is considered that potash application is too high. Tests caried out by the North Carolina State University indicate that there is no additional response by the plant above an application rate of 80 to 90 lbs K_2O per acre.

If the above is correct the fact, coupled with an assessment that growers will become larger and more efficient in the future, then there is a possibility of a reduction in application levels.

Outlook

There would appear to be no sign of an improvement in the US tobacco market, and a further decline in acreage and production may be expected in the immediate future. Increasing imports of lower priced tobacco leaf are putting more and more pressure on domestic producers to reduce prices. The export market for US producers is still considerable but is being eroded by non-competitive pricing situations. In addition there has been overproduction for many years stimulated in good part by a system of price supports which until recently made tobacco probably the most valuable cash crop in the US.

The level of future production will be determined to a considerable degree on the outcome of current negotiations directed at a lowering of the surplus stock and modifying the support system. If the programme as currently proposed goes ahead then a further decline in acreage and production can be expected for the next few years. Prices could fall by around 20% and this effect will be to reduce the number of smaller production units, but some sources consider that this will be compensated by the increase in the larger (100 acres plus) production units.

In North Carolina and South Carolina it appears that tobacco acreage accounts for virtually the total non-chloride application in the states. Potash consumption for the last three years for these states is tabluated over.

South Carolina: Potash Consumption

Year	Acres ('000)	Use on Tobacco lbs K_2O/acre	K_2O Cons. short ons	TOTAL Reported non-chloride Sales and consumption (i)
1982	59	218	6,431	6,102
1983	54	218	5,886	6,391
1984	48	204	4,896	7,033

North Carolina: Potash Consumption

1982	326	135	22,000	17,150
1983	278	135	18,765	19,120
1984	272	135	18,360	20,403

(i) PPI: Sales of sulphates plus state imports plus consumption of direct application potassium and sodium nitrates as reported by the USDA in their annual reports. Nitrates used in mixed goods (if any) are not reported.

Total US Flue Cured Tobacco Statistics

Year	Acres ('000)	Yield (lb/acre)	Supply/Demand Supply (MM lbs)	Supply/Demand Demand (MM lbs)	Total Stocks (MM lbs)	Stocks Under Loan* (MM lbs)
1975	717	1,973	1,415	1,193	1,652	180
1980	555	1,957	1,086	1,039	1,965	554
1981	541	2,164	1,144	1,012	2,013	596
1982	472	2,131	994	935	2,145	519
1983	410	2,004	855	894	2,205	688
1984	394	2,196	850	910	2,165	798
1985	361 (est)	2,025	731	n/a	2,105	860

* included in total stocks

Citrus Fruits

There is an increasing market within the US for citrus fruit. Per capita consumption has risen from under 100 lbs in 1970 to about 130 lbs in 1983 (the last years' figures available). With an increasing population the outlook for the end product looks favourable. Most of the increase in consumption has been from processed fruit, mainly as frozen concentrate.

However, the Florida citrus grower has been under increasing economic pressure over the past five years, and these pressures appear to be changing the face of the industry. Costs of production appear to have increased faster than prices. Land values, particularly those near retirement areas, have increased markedly and encouraged some growers, particularly on the smaller acreages to sell up.

The industry has also been hit by several years of exceptionally bad weather, the worst of which was the 1983 freeze which not only ruined the crop but also killed many trees. As a result of the freeze years of 1971, 1977, 1981, 1982 and 1983 the total acreage was reduced to 761,000 acres by 1983, compared to 971,000 acres in 1970. The 1983 freeze destroyed some 100,000 acres in eleven countries and as a result, production of oranges, the most important citrus crop, totalled only 117 million boxes in 1984, compared to over 200 million boxes in 1979/80.

In addition, foreign competition, particularly from Brazil, has kept prices low and has reduced unit profits concurrently with the fall in production in Florida.

As in many other areas of US agriculture the small and less efficient units are going out of business, being replaced by the larger commercial grower. This switch puts additional economic pressure on the industry due to the very long lead-time between an initial planting of an orchard and when it begins to earn any income (five years before any fruit and 25 years before full maturity).

Despite all these adverse factors The Florida Citrus Mutual and The University of Florida have both forecast that by the year 2000 the industry will be back to the levels of acreage and production of 1979/80.

This could be considered to be a slightly optimistic forecast but if the dietary habits of the US population continue on present trends the market for the end products will certainly be available. The main question is whether the new generation of citrus growers in Florida, with relatively high labour costs, will be in a position to compete with an ever growing competitive situation from Brazilian producers.

With respect to the consumption of potash on citrus in Florida the forecast of increased acreage is a positive factor. However, with the increase in the larger orchards operated by more cost-consious growers, application rates could be reduced to eliminate overfertilization, which often happens in the smaller family run units.

While the non-chloride forms of potash will continue to be used, agronomists see no sulphur deficiences but do indicate a lack of magnesium, which would point to a continued requirement for Sul-Po-Mag or equivalent. In many cases however magnesium can be supplied by dolomitic limestone at much lower costs. The potash product will increasingly be a granular product for use both as direct application material and in blended products, since many continuous ammoniation plants using a standard grade of material have closed down.

In the time available for field work it has not been possible to break out and quantify the non-chloride forms of potash used, with the exception of the direct application materials which are however only a small part of the total potash consumption.

SUMMARY

Although the Florida citrus industry continues to be under considerable economic pressures, the rebuilding of acreage after the succession of severe frosts could allow potash consumption on citrus fruits to increase very gradually at from 1.0 to 1.5% per annum.

Florida Commercial Citrus Acreage
('000 acres)

Census Year	Total	New Acreage Included	Acreage Lost
1970	941	36	26
1972	878	19	83 (1)
1974	864	26	40
1976	852	29	41
1978	831	28	49 (1)
1980	845	40	26
1982	848	55	52 (1)
1984	761	73	160 (1)

(1) Freeze years 1971, 1977, 1981, 1982, 1983

Source: Flue Crop and Livestock Reporting Service "Citrus" 9/84

Acreage by Crop
('000 acres)

	Oranges	Grapefruit	Special	Total
1970	716	124	101	941
1976	628	138	86	852
1980	627	140	78	845
1982	637	140	71	848
1984	574	135	52	761

Source: (IBID)

Production of Oranges
(MM metric tons)

	US	Brazil
1979/80	11.0	8.9
1980/81	9.7	9.2
1981/82	7.0	9.9
1982/83	8.8	9.2
1983/84 (1)	6.8	9.7

(1) Estimated

Source: "F/A. Ag. STAT", Citrus Summary 1984 P44

Use of Non-Chloride Potash Fertilizers-Florida
('000 short tons K_2O)

	P81(1)			USDH Consumption Direct Application (2)	
	Sales	Imports	Ftgr	Nitrate	Sodium Nitrate
1980	53.8	-	1979/80	-	-
1981	44.6	-	1980/81	-	-
1982	42.0	-	1981/82	2.5	5.8
1983	44.4	6.3	1982/83	1.8	6.7
1984	38.8	12.8	1983/84	1.5	6.5

(1) Potassium sulphates including potassium magnesium sulphates

(2) Additional tonnage included in consumption of mixed fertilizers

Stone Fruits

Some research has been carried out in the past by the Department of Soil Science, North Carolina State University on the use of non-chloride potash on stone fruits (particularly peaches). Some slight improvement in yield was noted but the gain in yield was not great enough to be statistically significant.

Over recent years there may have been a gradual loss of sulphur available to the trees by the use of low analysis fertilizers in the place of ammonium sulphate and normal superphosphate. The use of potassium sulphate as a source of sulphur in mixed formulations is also being examined. However, it is reported that it will be many years before statistically significant results are obtained.

Present day practice uses potassium chloride as the potash source for most stone fruits, but long term the trend may be towards potassium sulphate to obtain sulphur values. All stone fruits have a magnesium requirement but as in the case of tobacco and citrus fruits (q.v.) in most cases the grower can satisfy the magnesium requirement by the application of dolomitic limestone.

SUMMARY

It would appear that there is no real opportunity for an incremental use of non-chloride potash both in the short and medium term.

MARKETING CONCLUSIONS

Although the market for potassium sulphate on the tobacco crop in Eastern Canada and in the USA appears to be declining, in the longer-term consumption of potassium sulphate on other crops is expected to increase and to compensate for the decline on tobacco. There is a good opportunity for a producer in New Brunswick to supply these markets from a planned 30,000 t/a plant.

The logistics of movement from a New Brunswick location into Ontario and Quebec would allow the product to take the bulk of this market and the combination of low domestic freight costs to Saint John coupled with favourable ocean freight rates will allow easy penetration into the eastern seaboard of the United States.

Looking further ahead and considering a 100,000 or 200,000 tonnes per annum product plant, it will be essential to dedicate a proportion of these tonnages to offshore markets as, with increased competition from Israel and possibly from Jordan into US markets post 1990, coupled with the potential output of up to 300,000 tonnes of product from PCS in Saskatchewan, the market in the United States could at that time prove to be a difficult one.

Concurrently with the development of markets for up to 200,000 tonnes of product from a New Brunswick location, the production of synthetic potassium magnesium sulphate should also be undertaken, bearing in mind that of the non-chloride potash applications, up to 50% of the total K_2O consumption in certain Provinces and States is in the form of Sul-po-Mag or equivalent potassium magnesium sulphate product.

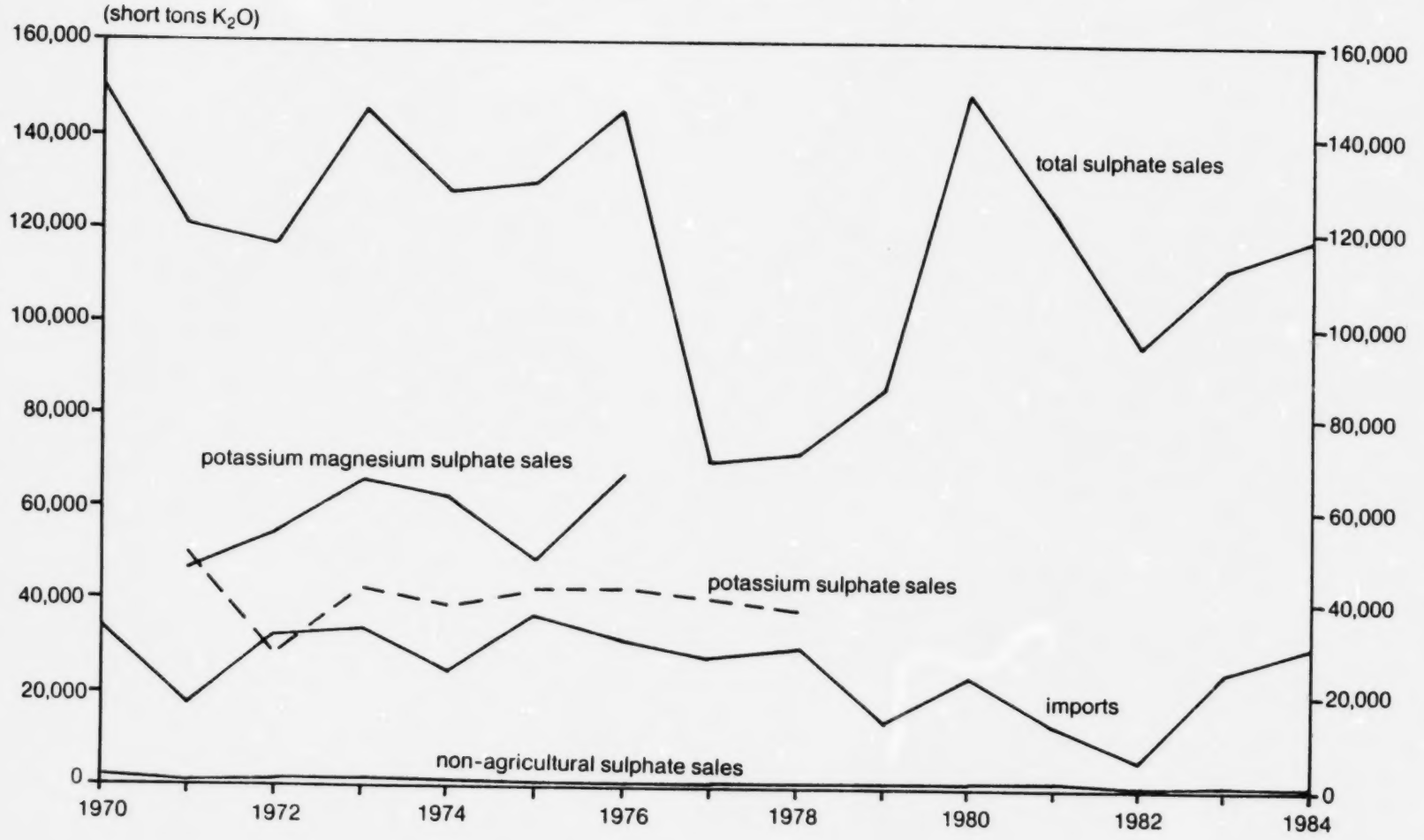
APPENDIX

East Coast USA States

Sales statistics for the following states are graphed in graph 2.

Alabama
Connecticut
Delaware
Florida
Georgia
Louisiana
Maine
Maryland
Massachusetts
Mississippi
New Hampshire
New Jersey
New York
North Carolina
Pennsylvania
Rhode Island
South Carolina
Virginia
Vermont

Potassium Sulphate and Potassium Magnesium Sulphate Sales – East Coast USA



N.B. 1. 1977 and 1978 – no potasium magnesium sulphate sales statistics available
N.B. 2. 1979 – potassium magnesium sulphate sales statistics for second half of year only

APPENDIX

Visit List

Canada

Dr. K. Pretty,
Senior Vice President International Programmes,
Potash and Phosphate Institute,
Toronto.

Mr. J. Cheval,
Manager,
Fertilizer Procurement & Distributin,
United Co-operatives of Ontario,
Mississauga.

Mr. D. Dolson,
Marketing Services Manager,
C.I.L. Inc.,
London,
Ontario.

Mr. W.R. Rigney,
Manager of Operations & Joint Ventures,
Cyanamid of Canada Inc.,
Willowdale,
Ontario.

Mr. N. Sheidow,
Tobacco Specialist,
Plant Industry Branch,
Ministry of Agriculture & Food,
Research Station,
Delhi,
Ontario.

Mr. Murray,
Chairman,
The Ontario Flue Cured Tobacco Grower's Marketing Board,
Tillsonburg,
Ontario.

Mr. B. Kilmer,
Fertilizer Institute of Ontario,
Mississauga,
Ontario.

Mr. R. Allman,
General Manager,
Bradford Fertilizer Ltd.,
Bradford,
Ontario.

Mr. J. Brown,
General Manager,
Canadian Fertilizer Institute,
Ottawa.

Mr. Kennedy,
Manager, Supply & Distribution,
Agrico Canada Ltd.,
Toronto.

Mr. C. Fisher,
Harrow Research Station,
Harrow,
Ontario.

Mr. Gilles D. Payette,
Vice President, Marketing,
Nutrite Inc.,
Brossard,
Quebec.

Ms. Lucille Mercier,
Quebec Fertilizer Manufacturers Association,
Montreal,
P.Q.

Mr. R. Latour,
Co-op Federee,
Montreal,
P.Q.

Mr. G. Gubbay,
William Houde,
Laprairie,
P.Q.

Mr. J.M. Harnois,
FERTICO,
Joilette,
P.Q.

United States

Dr. R. Koo,
Citrus Station,
Lake Alfred,
Fla.

Ms. Sunne Brandmeyer,
Economist,
Florida Citrus Mutual,
Lakeland,
Fla.

USDA Statistical Reporting Service,
Orlando,
Fla.
(Mrs N. Bourgois)

Dr. G. Green, III,
Pa. State Fruit Research Laboratory,
Beglesville,
Pa.

Dr. G.A. Cummings,
Department of Soil Science,
North Carolina State University,
Raleigh,
NC.

Mr. B. Segars,
Georgia Extention Service,
Athens,
Ga.

Mr. T. Williams,
Georgia Crop Reporting Service,
Athens,
Ga.

Mr. V. Grise,
Economic Research Service,
USDA,
Washington,
DC.

Dr. B. Kettrell,
PEE DEE Extension Service,
Florence,
SC.

Dr. G. Peedin,
North Carolina State University,
Raleigh,
NC.